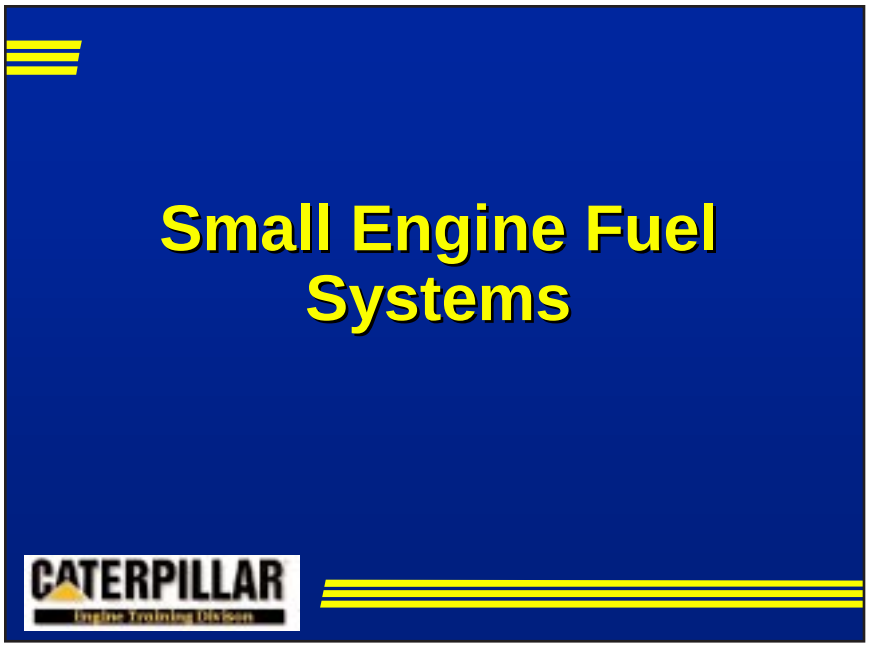
CATERPILLAR

ENGINE COURSE BOOK



SMALL ENGINE FUEL SYSTEMS

COURSE DESCRIPTION

Small Engine Fuel Systems

Content

4 1/2 Days

2050

None

This course is an in-depth study of the Caterpillar fuel systems for the 3114, 3116, 3126/3126B/E, C-9 and 3208 engines. Participants will learn to test and adjust the 1.1 and 1.2 liter mechanical and HEUI fuel systems and the sleeve metering fuel system used on the 3208 engines. Caterpillar fuel injection pumps, governors, unit injectors, and nozzles will be studied.

- Explain the relationship of horsepower, rack, boost, fuel rate, torque and BSFC
- Explain the engine operating tolerances and the relationship of density of fuel and air to engine performance
- Explain the operating principles of the mechanical unit injectors, HEUI fuel systems and sleeve metering fuel systems.

Audience

- Demonstrate the adjustments of 1.1 liter and 3208 governors.
- Demonstrate the removal and installation of a 1.2 liter HEUI injector and Injector sleeve.
- Test 7000 series, capsule and pencil nozzles.
- Check and adjust fuel settings.
- Check and adjust unit injector synchronization and timing.
- Explain the operation of the C-9 fuel system

Students attending this course must be able to use the service manual and Caterpillar fuel system tools. Participants must also have a basic knowledge of diesel engine systems. Priority will be given to individuals designated by dealerships to become a Certified Engine Instructor.

References

Students attending will be asked to bring approved safety glasses and wear only rigid style shoes. (No canvas tennis shoes or open toe shoes). Students should also bring a calculator.

Small Engine Fuel Systems

Schedule

Day	Sec.	Subject	Time	
Monday	1	Introduction and Pre-Test	8:00	9:00
	2	Fuel Selection	9:00	9:30
		Break	9:30	9:45
		Fuel Selection	9:45	10:30
	3	Fuel Related Problems	10:30	11:00
		Lunch	11:00	11:45
	3	Fuel Related Problems	11:45	12:15
	4	Basic Governor Theory	12:15	12:30
	5	Performance Curves	12:30	2:30
		Break	2:30	2:45
	6	Horsepower Correction Factors	2:45	4:00
Tuesday	7	Quiz 1	8:00	8:30
	8	Fuel Setting Information	8:30	9:30
		Break	9:30	9:45
	9	1.1/1.2 MUI Fuel System Introduction	9:45	11:00
	10	Injector Adjustment Lab	11:00	11:30
		Lunch	11:30	12:15
		Injector Adjustment Lab	12:15	2:30
		Break	2:30	2:45
		Injector Adjustment Lab	2:45	3:00
	11	Governor Disassembly & Assembly	3:00	4:00
Wednesday		Governor Disassembly & Assembly	8:00	9:00
	12	Quiz 2	9:00	9:30

		Break	9:30	9:45
	13	Governor Test Stand Lab	9:45	11:30
		Lunch	11:30	12:15
		Governor Test Stand Lab	12:15	12:45
	14	1.1/1.2 Injector Sleeve Lab	12:45	2:30
		Break	2:30	2:45
	15	Introduction to 1.1/1.2 HEUI Fuel Systems	2:45	4:00
Thursday		Introduction to 1.1/1.2 HEUI Fuel Systems	8:00	8:45
	16	Quiz 3	8:45	9:15
		Break	9:15	9:30
	17	Introduction to C-9 HEUI Fuel System	9:30	11:15
		Lunch	11:15	12:00
	18	Introduction to 3208 Fuel System	12:00	1:00
	19	3208 Lab	1:00	2:30
		Break	2:30	2:45
	19	Intro to Fuel Lines & Nozzles	2:45	4:00
Friday		Intro to Fuel Lines & Nozzles	8:00	8:15
	20	Nozzle Test Lab	8:15	9:15
		Break	9:15	9:30
	20	Nozzle Test Lab	9:30	10:00
	23	Final and Course Evaluation	10:00	11:30

Small Engine Fuel Systems

Literature List

Registration Form	Copy
Small Engine Fuel System Schedule	Copy
Glossary of Terms	LEXQ9297
Pre-Test	Copy
Fuel Selection Slide Script	Copy
Diesel Fuel and Your Engine	SEBD0717
Engine Performance Reference	LEXT1044
Blending Used Crankcase Oil	LEKQ6070
Blending Used Crankcase Oil for use with Cat HD Diesel Engines	LEKQ6071
Basic Governor Theory Slide Script	Copy
Power Curve Slide Script	Copy
Test Condition Slide Script	Copy
Sample 0T/2T Information from the TMI/SIS or SIS Web	Copy
Sample Engine Performance Information from the TMI on-line system	Copy
Quiz 1	Copy
1.1 Liter Fuel System Slide Script	Copy
Systems Operation T & A, 3114, 3116, 3126 Engines	SENR3583
Torque Specifications	SENR3130
Using the 128-8822 Tool Group on 3114, 3116, & 3126 Engines	HEHS0610
Service Manual, 3114, 3116, 3126 Engine Governor	SENR6454
Quiz 2	Copy
Using the 143-2099 Sleeve Replacement Tool Group	NEHS0675
1.1 and 1.2 HEUI Fuel System Slide Script	Copy
Quiz 3	Copy
C-9 Fuel System Slide Script	Copy
HEUI HI300B Fuel System	RENR1392

6V4141 Sleeve Calibration Tool	SMHS 7835
5P6577 Fuel Setting Tool Group	SMHS7013
Analyzing Fuel Nozzle and Fuel Line Failures	SEBD0639
Using the 5P4150 Nozzle Testing Group	SEHS7292
Test Sequence for Capsule Type Fuel Nozzles	SEHS7350
Test Sequence for 7000 Series Fuel Nozzles	SEHS9083
Test Sequence for Pencil-Type Fuel Nozzles	SEHS7390
Final Test	Copy
Course Evaluation Sheet	Copy

Small Engine Fuel Systems

Student Literature List

Registration Form	Copy
Small Engine Fuel System Schedule	Copy
Pre-Test	Copy
Engine Performance Reference	LEXT1044
Sample 0T/2T Information from the TMI/SIS or SIS Web	Copy
Sample Engine Performance Information from the TMI on-line system	Copy
Quiz 1	Copy
Quiz 2	Copy
Quiz 3	Copy
Final Test	Copy
Course Evaluation Sheet	Copy

Small Engine Fuel Systems

Hardware List

Slide Projector

Screen

Fuel Selection Slides

1P7408 Thermo-hydrometer

5P2712 Thermo-hydrometer

1P7438 Beakers

Various fuel samples

Basic Governor Slides

Power Curve Slides

Calculator

Test Conditions Slide

On-line Terminal

1.1 Liter Fuel System Slides

1.1 or 1.2 liter Mechanical Engine

128-8822 Tool Group

Hand Tools

1.1 or 1.2 Mechanical Governor

128-8822 1.1 Liter Engine Injector Tool Group

1U7315 1.1 Liter Engine Governor Tool Group

1U7326 Governor Calibration Bench

1U9786 Calibration Pin

1U6673 FRC Adjustment Wrench

1U9893 Solenoid Spanner Wrinch

6V6106 Dial Indicator

1U8815 Contact Point

15 psi Air Supply

143-2099 Sleeve Replacement Tool Group

1.1 and 1.2 HEUI Fuel System Slides

C-9 HEUI Fuel System Slides

HEUI HI300B CD

PC Computer

3208 Fuel System Slides

3208 Engine with Pump and Governor

6V4141 Sleeve Calibration Tool Group

5P6577 Fuel Setting Tool Group

5P4150 Nozzle Test Group

Various Fuel Nozzles

Small Engine Fuel Systems

Lesson Plan 1 - Introduction & Pre-test

Objectives:

- The instructor will complete all administrative duties required for class start up.
- The instructor will explain the course objectives and course schedule to the students and answer any questions concerning them.
- The instructor will explain course safety procedures.
- The instructor will provide an introduction of himself, classmates and training facility.
- The student will take a pre-test so the instructor can gain knowledge of the experience level of the course participants so the instructor can select the proper level to present the subject matter.

Literature Needed:

Registration Form	Copy
Small Engine Fuel System Schedule	Copy
Glossary of Terms	LEXQ9297
Pre-Test	Copy

Hardware Needed:

None

Time Required:

1 Hour

Tasks Required by Instructor to Meet Objectives:

1. Fill out registration forms.
2. Introduce self and students.
3. Explain course objectives, schedule, and safety procedures.
4. Review how to use the Glossary of Terms.
5. Administer and review pre-test with the students.

Small Engine Fuel Systems

Lesson Plan 1 - Pre-Test

Select the best answer

1. The spring force in a governor:
   A. Increases fuel rack hunting.
   B. Does not affect the fuel rack.
   C. Moves the fuel rack toward the fuel on position.
   D. Prevents rack movement.
   E. Moves the fuel rack toward the fuel off position.

2. How can rated load rpm be increased?
   A. Increase the rack setting
   B. Increase high idle
   C. Increase fuel pressure
   D. Increase the torque setting

3. If the A.P.I. of the fuel is lowered, the BTU content will go:
   A. Up
   B. Down
   C. Remain the same

4. In the hydra-mechanical governor, oil pressure is used to:
   A. Compress the governor spring
   B. Lubricate governor parts only
   C. Move the flyweights
   D. Move the rack

5. The governor flyweights:
   A. Prevents fuel rack movement
   B. Moves the rack toward the fuel off position
   C. Moves the rack toward the fuel on position
   D. Does not affect the fuel rack.

6. The purpose of the fuel ratio control is to:
   A. Prevent turbocharger overspeed
   B. Limit maximum horsepower
   C. Eliminate excessive smoke during acceleration
   D. To limit engine RPM until oil pressure builds up

7. What is or causes black smoke?
   A. Unburned fuel
   B. Worn valve guides
   C. Overfueling
   D. Cracked cylinder liner

8. What is or causes white smoke?
   A. Burning oil
   B. Overfueling
   C. Incomplete combustion
   D. A and C
   E. None of the above

9. Which of the following can cause excessive black smoke?
   A. Advanced timing
   B. High rack setting
   C. A and B
   D. None of the above

10. Which of the following can cause a low power complaint?
   A. Using #2 diesel fuel instead of #1 diesel fuel
   B. Air inlet restriction of 15 inches of water
   C. Exhaust back pressure of 10 inches of water
   D. Mis-adjusted or bent accelerator linkage

11. Which of the following can cause a low power complaint?
   A. Cloud point of the fuel too low
   B. 37.2 API fuel and 90 degrees F
   C. Cetane of the fuel too high
   D. Increased altitude

12. A gallon of diesel fuel has more B.T.U.'s than a gallon of gasoline.
   A. True
   B. False

13. The best way to lower cloud point of a diesel fuel:
   A. Add alcohol
   B. Add gasoline
   C Add #1 diesel
   D Add cetane
   E. All the above

14. A diesel fuel with a low cetane number can result in:
    A. Hard starting
    B. White smoke at startup
    C. Black smoke under load
    D. Fuel filter plugging
    E. A and B
    F. A and C

15. The high idle adjustment can be made on the engine on a 3116 engine.
    A. True
    B. False

16. The purpose of transfer pump pressure is:
    A. to increase engine horsepower
    B. to disipate the water in the fuel
    C. to properly fill the plunger and barrel assemby
    D. to prevent filter plugging

17. The horsepower tolerance for a Caterpillar engine with less than 100,000 miles is:
    A. ± 5%
    B. ± 3%
    C. +5% -3%
    D. +7% -5%

18. As inlet fuel temperature increases:
    A. Maximum horsepower of the engine increases
    B. Maximum horsepower of the engine decreases
    C. Boost pressure increases
    D. The fuel becomes more dense

19. It is recommended to use fuel heaters to overcome the effects of cold weather on fuels.

    A. True

    B. False

20. Which of the 1.1 liter governor types use four governor flyweights to control rack movement?

    A. Type 1

    B. Type 2

    C. Type 3

    D. Type 4

    E. Type 5

Small Engine Fuel Systems

Lesson Plan 1 - Pre-Test Master

Select the best answer

1. The spring force in a governor: C
   A. Increases fuel rack hunting.
   B. Does not affect the fuel rack.
   C. Moves the fuel rack toward the fuel on position.
   D. Prevents rack movement.
   E. Moves the fuel rack toward the fuel off position.

2. How can rated load rpm be increased? B
   A. Increase the rack setting
   B. Increase high idle
   C. Increase fuel pressure
   D. Increase the torque setting

3. If the A.P.I. of the fuel is lowered, the BTU content will go: A
   A. Up
   B. Down
   C. Remain the same

4. In the hydra-mechanical governor, oil pressure is used to: D
   A. Compress the governor spring
   B. Lubricate governor parts only
   C. Move the flyweights
   D. Move the rack

5. The governor flyweights: B
   A. Prevents fuel rack movement
   B. Moves the rack toward the fuel off position
   C. Moves the rack toward the fuel on position
   D. Does not affect the fuel rack.

6. The purpose of the fuel ratio control is to: C
   A. Prevent turbocharger overspeed
   B. Limit maximum horsepower
   C. Eliminate excessive smoke during acceleration
   D. To limit engine RPM until oil pressure builds up

7. What is or causes black smoke? C
   A. Unburned fuel
   B. Worn valve guides
   C. Overfueling
   D. Cracked cylinder liner

8. What is or causes white smoke? E
   A. Burning oil
   B. Overfueling
   C. Incomplete combustion
   D. A and C
   E. None of the above

9. Which of the following can cause excessive black smoke? B

   A. Advanced timing

   B. High rack setting

   C. A and B

   D. None of the above

10. Which of the following can cause a low power complaint? D

   A. Using #2 diesel fuel instead of #1 diesel fuel

   B. Air inlet restriction of 15 inches of water

   C. Exhaust back pressure of 10 inches of water

   D. Mis-adjusted or bent accelerator linkage

11. Which of the following can cause a low power complaint? D

   A. Cloud point of the fuel too low

   B. 37.2 API fuel and 90 degrees F

   C. Cetane of the fuel too high

   D. Increased altitude

12. A gallon of diesel fuel has more B.T.U.'s than a gallon of gasoline. A

   A. True

   B. False

13. The best way to lower cloud point of a diesel fuel: C

   A. Add alcohol

   B. Add gasoline

   C Add #1 diesel

   D Add cetane

   E. All the above

14. A diesel fuel with a low cetane number can result in: E

    A. Hard starting

    B. White smoke at startup

    C. Black smoke under load

    D. Fuel filter plugging

    E. A and B

    F. A and C

15. The high idle adjustment can be made on the engine on a 3116 engine. B

    A. True

    B. False

16. The purpose of transfer pump pressure is: C

    A. to increase engine horsepower

    B. to disipate the water in the fuel

    C. to properly fill the plunger and barrel assemby

    D. to prevent filter plugging

17. The horsepower tolerance for a Caterpillar engine with less than 100,000 miles is: B

    A. ± 5%

    B. ± 3%

    C. +5% -3%

    D. +7% -5%

18. As inlet fuel temperature increases: B

    A. Maximum horsepower of the engine increases

    B. Maximum horsepower of the engine decreases

    C. Boost pressure increases

    D. The fuel becomes more dense

19. It is recommended to use fuel heaters to overcome the effects of cold weather on fuels. A

    A. True

    B. False

20. Which of the 1.1 liter governor types use four governor flyweights to control rack movement? B

    A. Type 1

    B. Type 2

    C. Type 3

    D. Type 4

    E. Type 5

Small Engine Fuel Systems

Lesson Plan 2 - Fuel Selection

Objectives:

- The student, on a written test, will be able to explain the characteristics of diesel fuels with at least 70% accuracy.
- The student will be able to select proper fuels for Caterpillar engines on a written test with at least 70% accuracy.
- The student, on a written test, will be able to explain proper fuel system maintenance procedures for Caterpillar engines with at least 70% accuracy.

Literature Needed:

Fuel Selection Slide Script	Copy
Diesel Fuel and Your Engine	SEBD0717

Hardware Needed:

Projector

Screen

Fuel Selection Slides

Time Required:

1.25 Hours

Tasks Required by Instructor to Meet Objectives:

1. Review the slides and emphasize the following points:
   A. Preferred fuels
   B. The function of cetane in the fuel
   C. Water and sediment in the fuel
   D. The effect of low temperature on a fuel
      1. Cloud point
      2. Pour point
   E. Methods of changing cloud / pour point of fuel

1. Gasoline
2. Alcohol
3. #1 Diesel

F. Sulfur in the fuel

2. Using Diesel Fuels and Your Engine, emphasize the following points not on the slide program:

A. The expense of fuel relative to other engine operating costs.

B. Fuel contaminants

C. The effects of poor fuel quality on the engine.

D. Charts of acceptable limits and problems and causes.

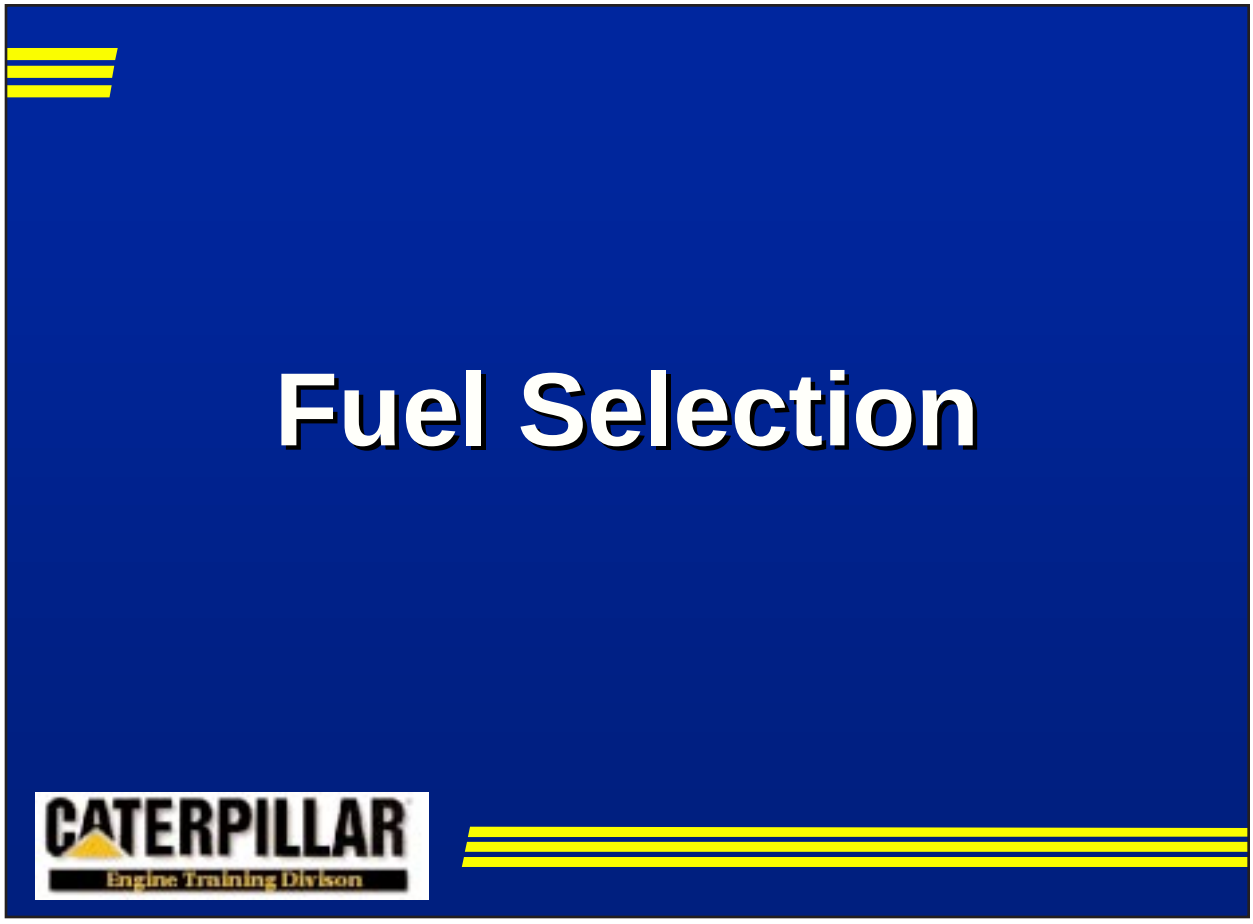
E. Precombustion vs. Direct Injection

F. Fuel system maintenance

3. Ask if there are any questions and review any areas that might be unclear.

SLIDE 1

During this course we will be discussing various types of fuel systems used on our medium duty Caterpillar engines. Before we can discuss various fuel systems, we must first talk about what they pump: Fuel

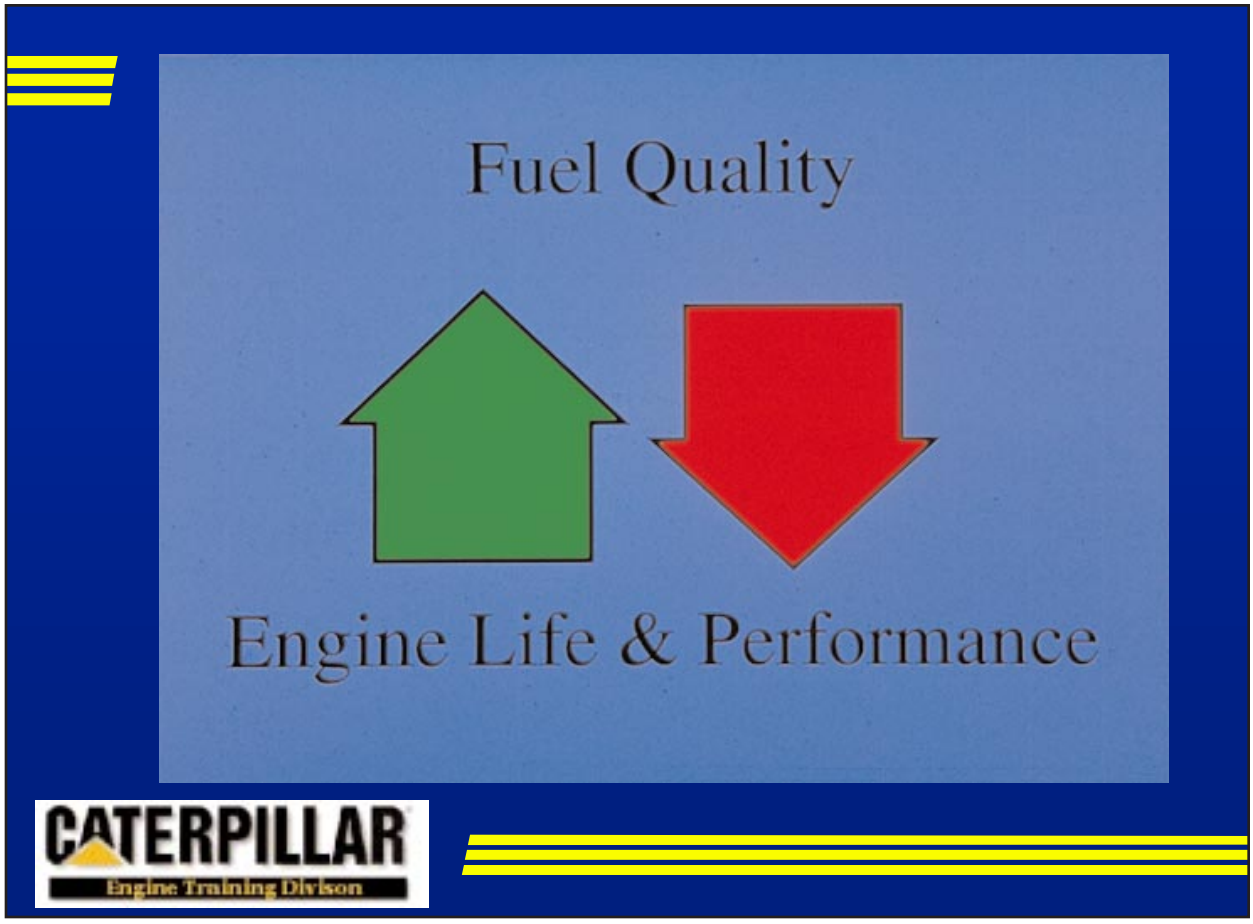


SLIDE 2

Attributes of fuel

Engine performance

We will discuss the attributes of fuel and how it affects the performance of a diesel engine. Many people think that all fuel is the same, and that it does not change engine performance. The inverse is probably more correct. During the next few minutes we will explore some of the differences that can be found in different fuels.



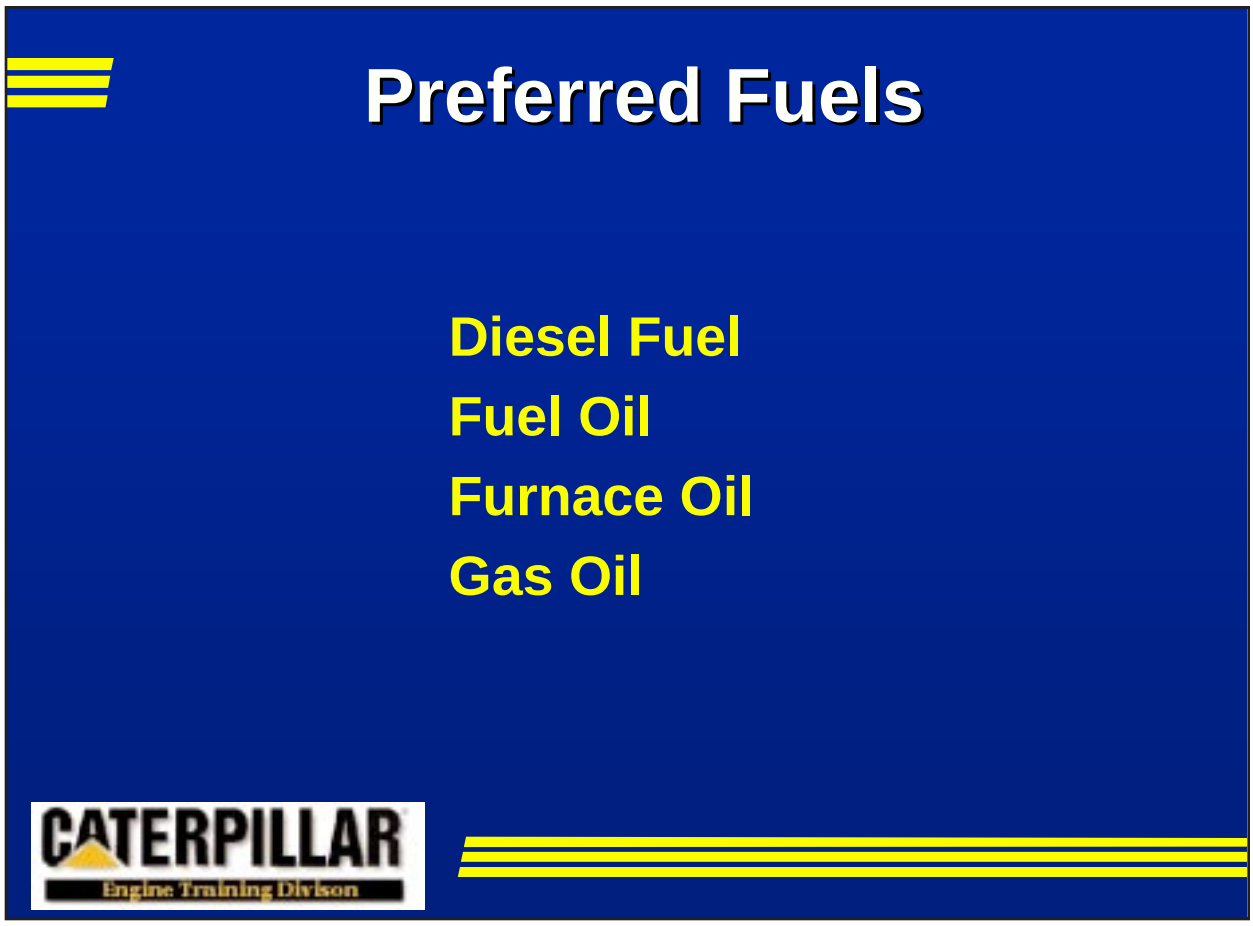
SLIDE 3

Service life

Performance

Fuel selection

Caterpillar wants its customers to get the maximum service life from their engines with a minimum of downtime. One method to assure good continuous engine performance is to select the best available fuel. Fuel quality is critical to engine life and good performance. Although called diesel fuel, the exact mixture could be slightly different with every fill up. Therefore, with every fill up, the engine may perform differently.



SLIDE 4

Preferred Fuels

Distillate fuels

Diesel fuel

Fuel oil

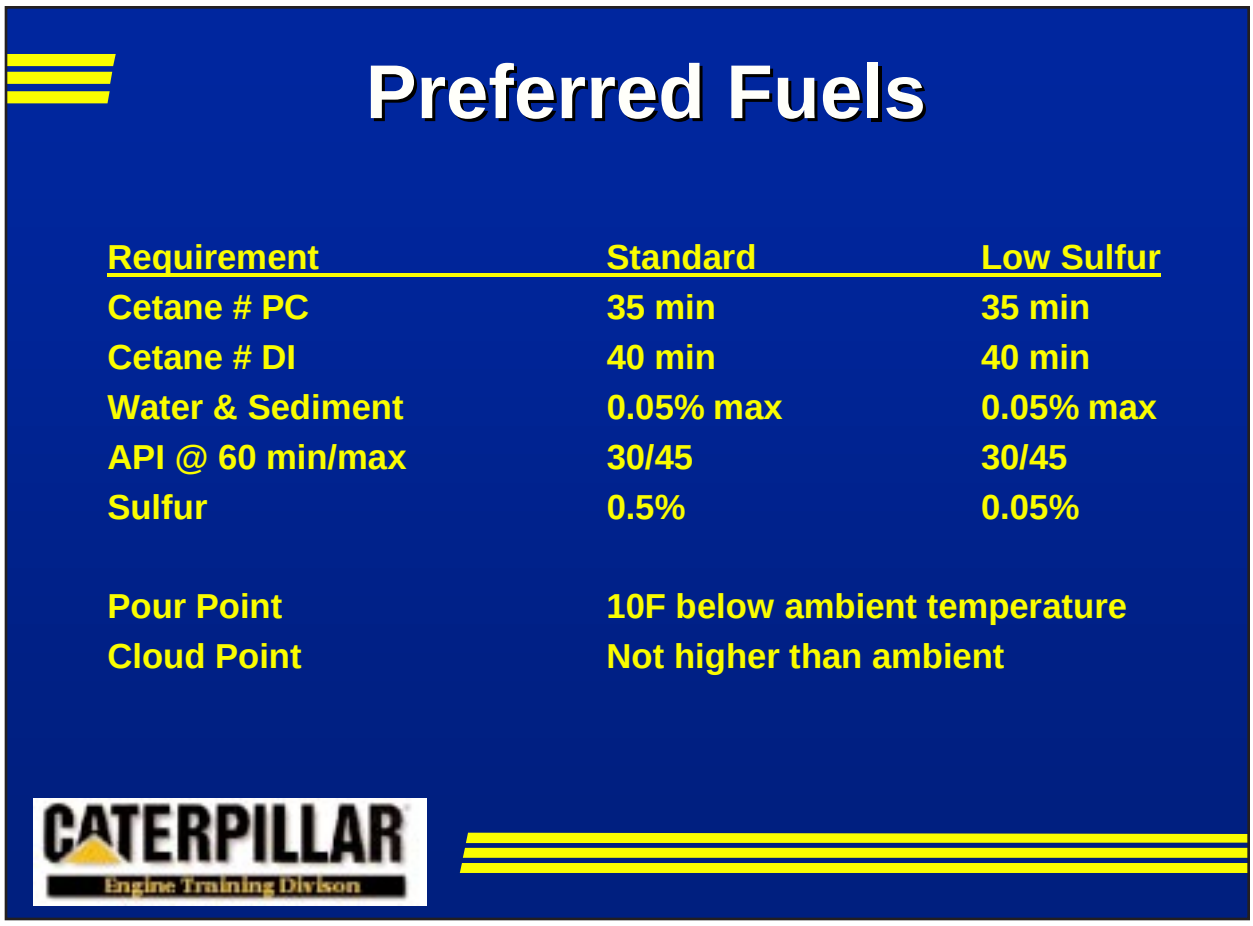
Gas oil

Kerosene

Maximum life

Caterpillar engines have the ability to burn a wide range of fuels. Distillate fuels are the preferred fuels for use in Caterpillar engines. Those fuels are commonly called diesel fuel (number 1 or 2), fuel oil, furnace oil, gas oil or kerosene.

Experience has proven that the use of distillate fuels will result in maximum engine service life, performance and durability. Distillate fuels usually contain smaller amounts of water, sulfur and sediment than the second type of fuels, permissible.



SLIDE 5

Standard sulfur 0.5%

Low sulfur 0.05%

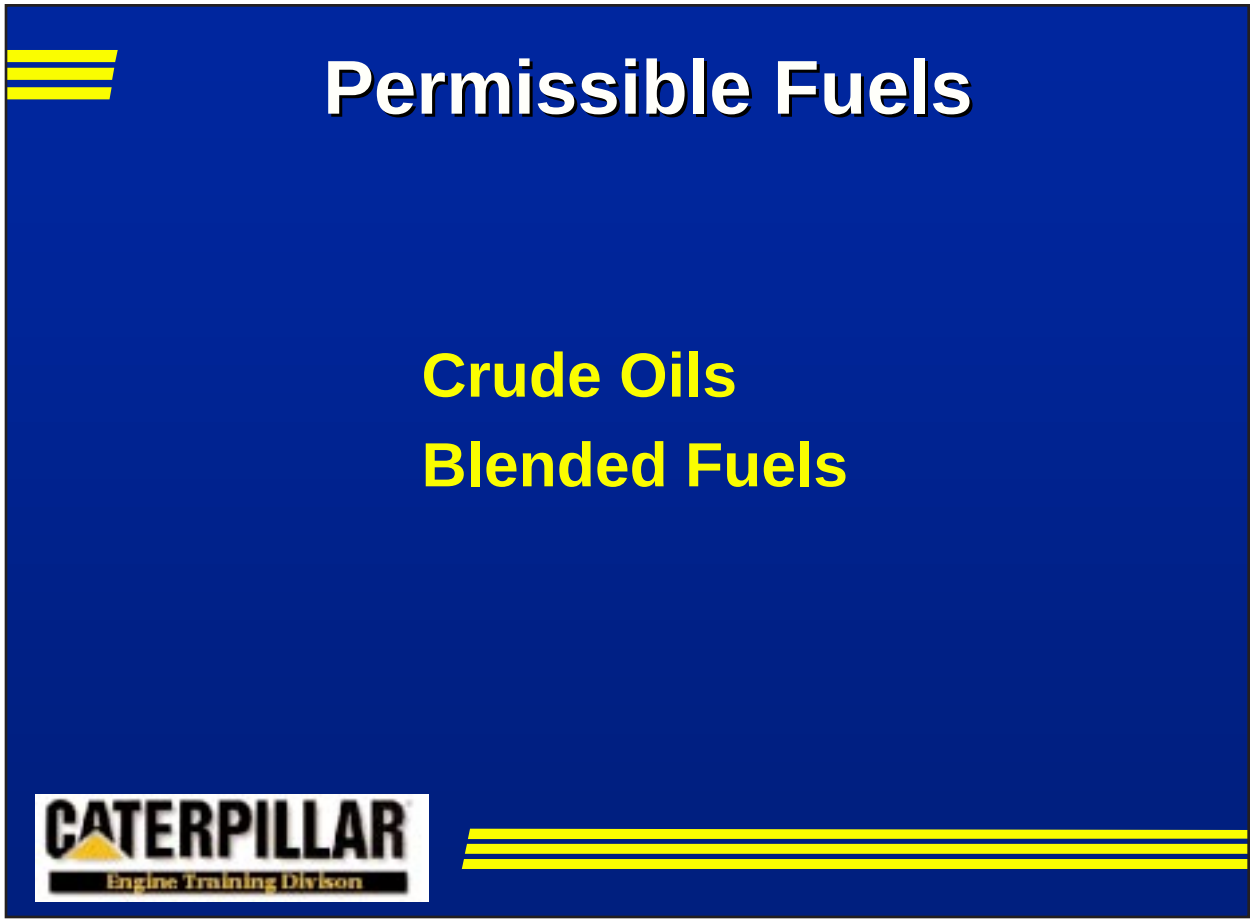
Here are the Caterpillar specifications for preferred fuels. It is separated into two groups. Standard fuel, and low sulfur fuel. It should be noted that the only variation between the two columns is the amount of sulfur contained in the fuel.

Each type (diesel fuel, fuel oil, furnace oil, kerosene) of preferred fuels can be put into either category depending on sulfur content.

Standard fuel, 0.5% sulfur maximum (5,000 parts per million), is available for off highway use in heavy equipment, industrial engines and commercial marine applications in the United States and Canada. For identity of this fuel, the governments require a dye to be added.

Low sulfur fuel, 0.05% sulfur maximum (500 parts per million), is required for use on highway trucks and pleasure craft marine applications in the United States and Canada. No dye is added to this fuel. It is almost clear with a slight yellow green tint.

As emission standards get tighter, new fuels are already available. The next step will be diesel fuels with 0.015% sulfur maximum (150 parts per million). These fuels will be required for on-highway use in 2007. They are currently in use for ultra low emissions vehicles.



SLIDE 6

Permissible fuel

Crude oil

Blended fuel

Serviced life

Treatment

Centrifuge

Heating

Reducing life

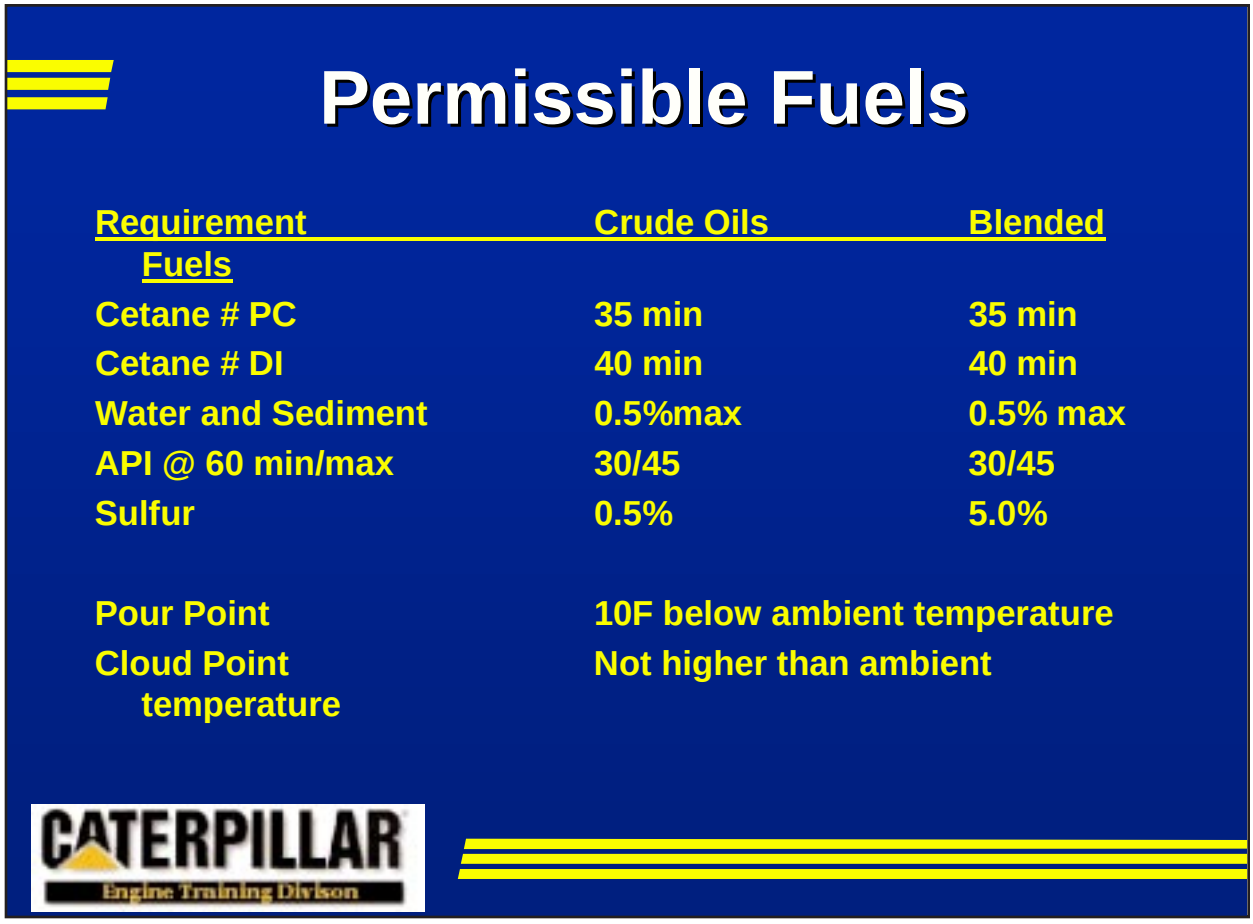
Increased maintenance

The use of some crude oils and blended fuels, is permissible in some Caterpillar engines. These engines require a special fuel system to tolerate the differences of these fuels.

Crude oil is oil or fuel that is not yet refined or fully refined, and is basically the same as it was originally pumped from the ground.

Blended fuel, sometimes called heavy or residual fuel, is composed of the remaining elements from crude oil after the oil has been refined into diesel fuel or gasoline. These elements can be combined or diluted with a lighter fuel so they can flow. At times these fuels have to be heated or centrifuged to be used.

If crude oil or blended fuels are used, additional service procedures may be required, and reduced service life may be experienced.



SLIDE 7

Crude oil

Blended fuel

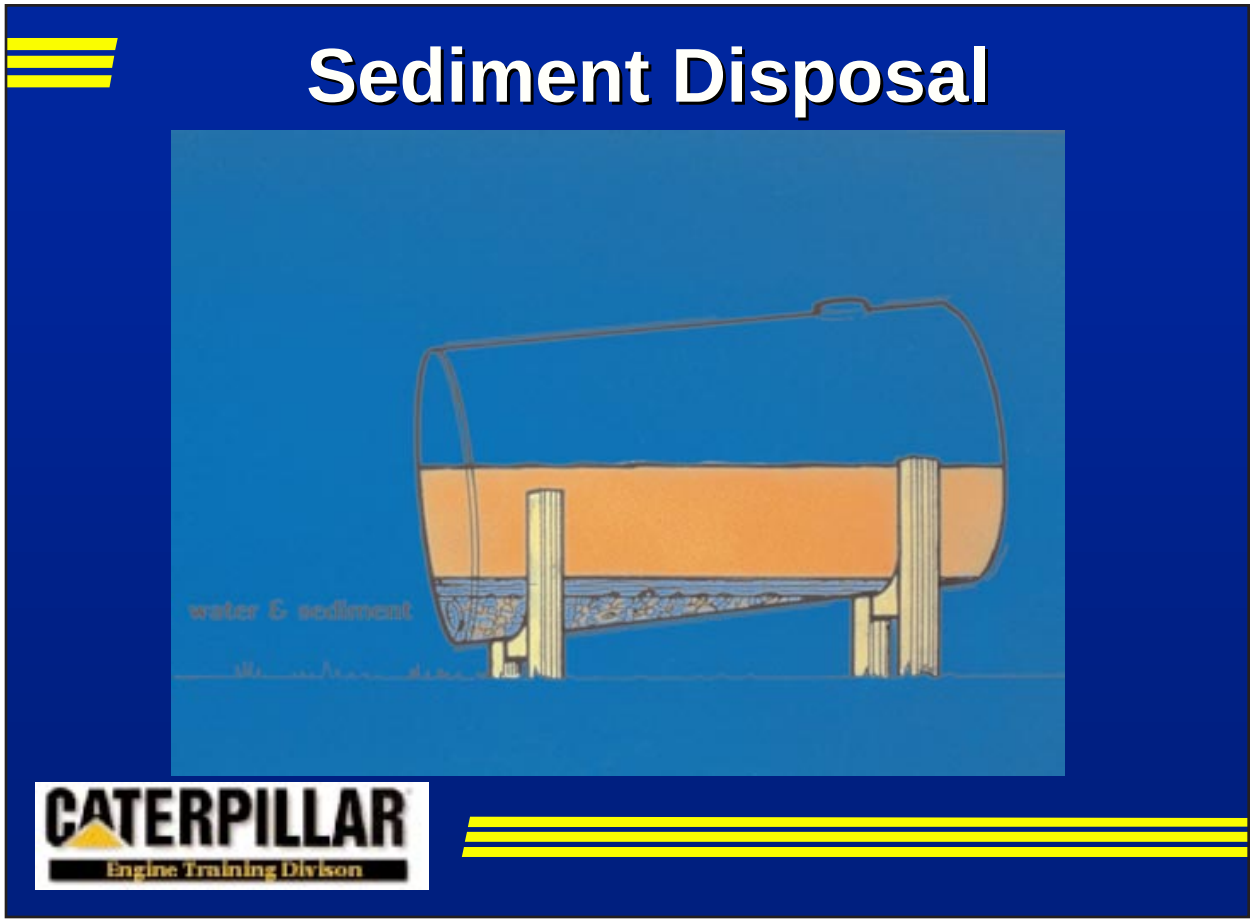
Water, sediment, trace metals

Sulfur content

Here are the Caterpillar specifications for permissible fuels. Again, it is separated into two groups, crude oil, and blended fuel. It should be noted that these fuels are allowed higher concentrations of water and sediment than are the preferred fuels.

Because they can contain higher levels of water, sediment and trace metals, the owner may need to monitor and evaluate oil change intervals and use extra filtration to remove solids and/or install fuel heaters and centrifuges to make the fuel pumpable.

Also note the difference in sulfur content between crude oil and the blended fuel.



SLIDE 8

Fuel storage tanks

Tank construction

Drained periodically

Waste handling

Crude oil, blended fuel and even distilled fuels may contain excessive amounts of water and/or sediment which require pre- treatment before delivery to the fuel injection system. Some of these contaminants can be removed by using a settling tank. Fuel storage tanks should be constructed on an angle so water and sediment will settle in the low end. Contaminants can then be drained off periodically. Care must be taken when disposing of the material drained off, since it is considered hazardous waste in some areas. Water in the fuel storage tanks can also lead to the growth of bacteria. These bacteria can plug fuel filters, causing low power in engines. Storage tanks should be checked for bacterial growth. There are fuel and water soluble additives which can be added to storage tanks to control bacteria.

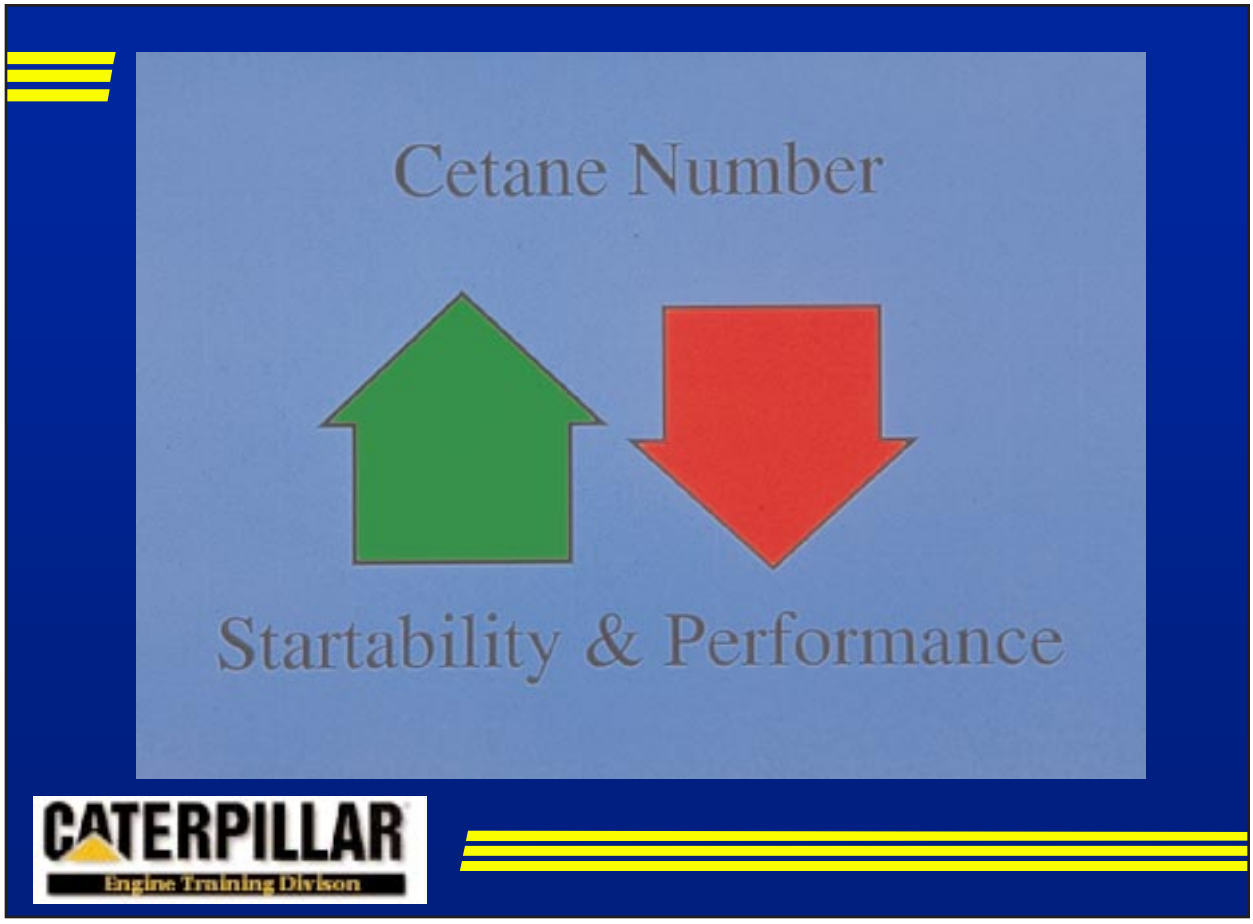
SLIDE 9

Water separator

Proper maintenance

Water capacity

The water separator should be installed between the tank and the rest of the system for best operation. Water which remains in the fuel can be taken out by a water separator in most cases. In severe applications, a large capacity water separator can be used. A water separator is only as good as its maintenance. The water must be drained off before the rated water capacity of the unit is reached. Once the water holding capacity of the separator is reached, all additional water will pass through the separator.



SLIDE 10

Fuel cetane rating

Ignition quality

Startability

Performance

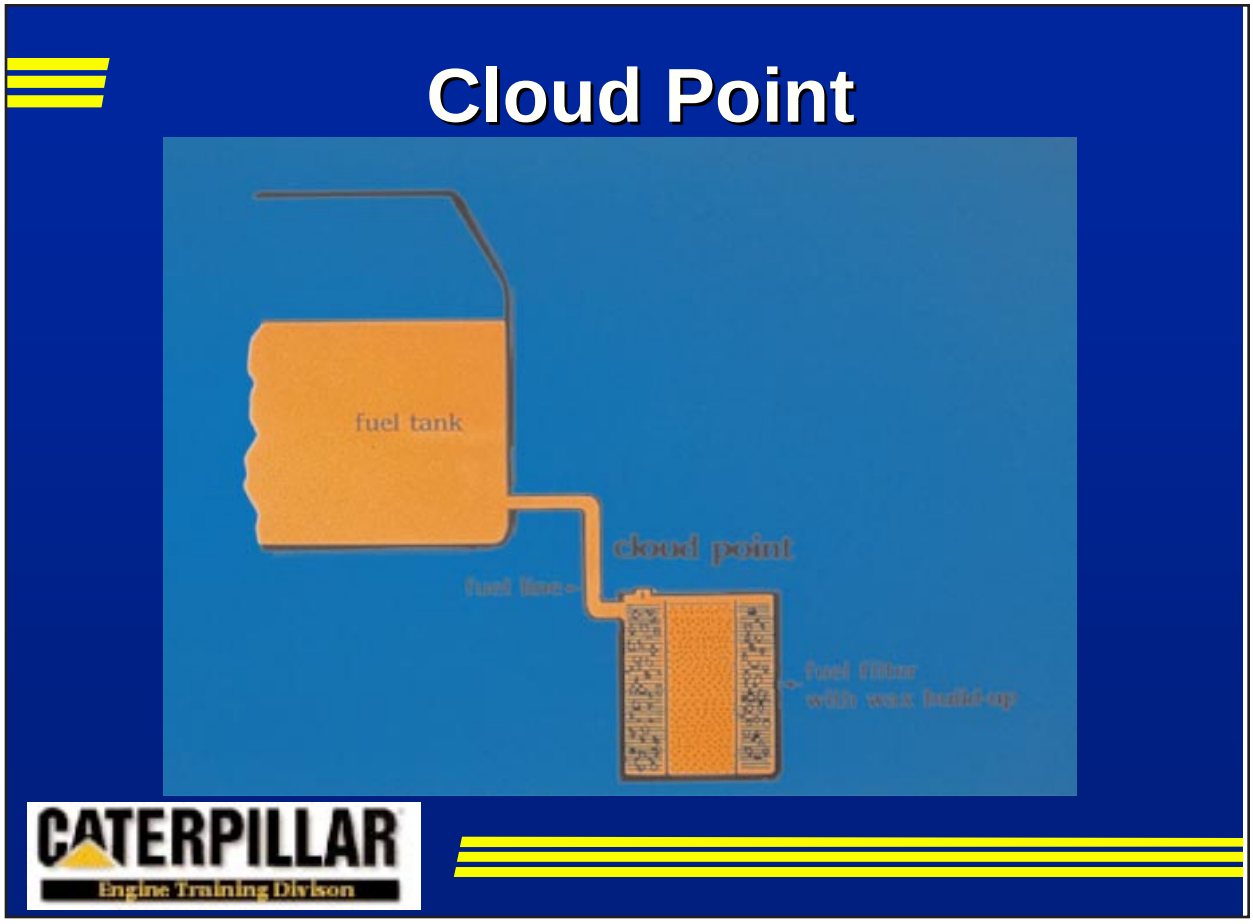
White smoke

35 for PC engines

40 for DI engines

Cetane is a chemical found naturally in fuel. The Cetane number (the amount of the cetane present in the fuel) is a measurement of the ignition quality of a fuel. Engine startability and acceleration under load are especially sensitive to the fuel cetane rating. A higher cetane rating assures ease of starting in most conditions. Fuels must have a minimum cetane number of 35 for precombustion chamber engines and 40 for direct injection engines. Fuel with cetane levels lower than minimum can cause hard starting, white smoke at start-up and poor engine performance.

Generally, an increase of ten in the cetane number will lower the temperature at which the engine can be started approximately 12º to 15ºF



SLIDE 11

Cloud point

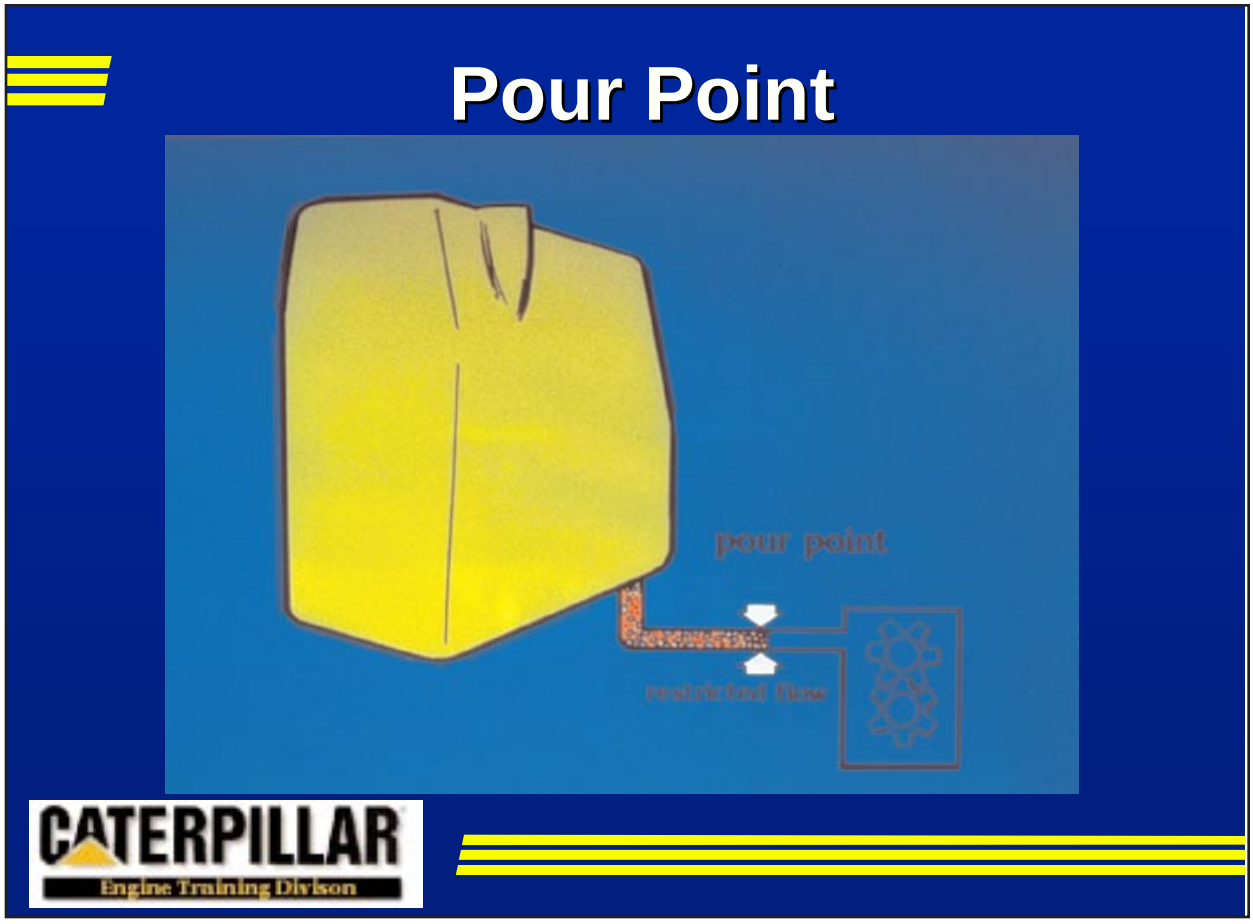
Wax content

Filter pluging

Temperature

At low temperatures, any fuel may contain solid particles of wax which could plug the filters rapidly. The cloud point of fuel is the temperature at which some of the heavier paraffin components (wax) start to form crystals. This is a natural process as the temperature is causing the fuel to begin its change from liquid to solid. These wax crystals give the fuel a cloudy appearance. This wax is not a contaminant, but is an important element of diesel fuel and has a high energy content and a very high cetane value. The cloud point of the fuel is important because this wax can plug the fuel filter.

If the cloud point of the fuel is lower than the lowest ambient temperature at which the engine will be expected to start and operate, filter plugging will not be a problem.



SLIDE 12

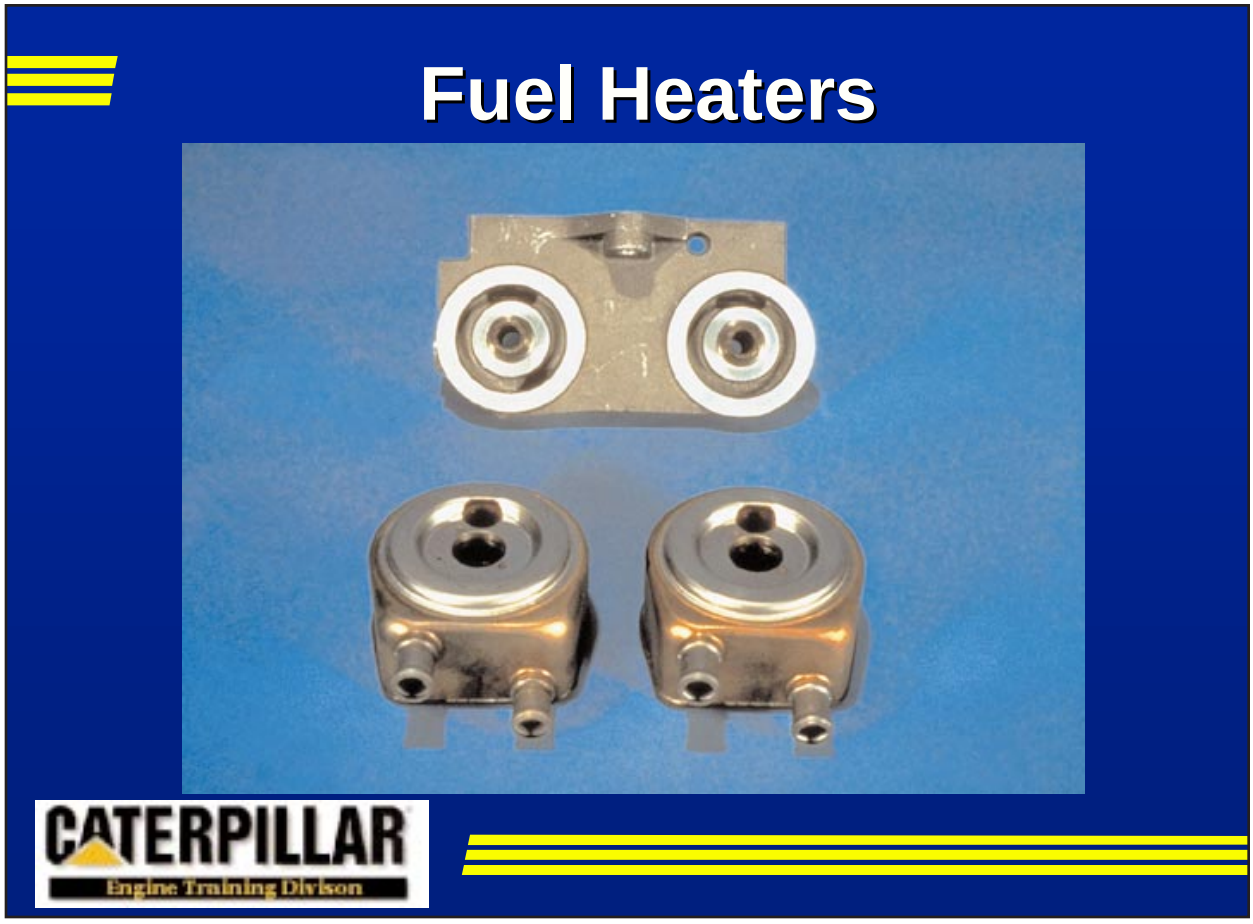
Pour point

Minimum temperature that fuel will flow

About 10o F below cloud point

The pour point of a fuel is an indication of the minimum temperature at which the fuel will flow. At the pour point temperature, the amount of wax crystals increases to a point where they connect together. This can restrict the flow of fuel from the tank to the engine transfer pump, but if the fuel stays around the fuel pick up tube, the transfer pump will move it. The pour point is approximately 10° F below the cloud point.

The pour point can be improved with flow improvers or the addition of kerosene or a lighter diesel. Fuel heaters cannot always solve problems related to a high pour point temperature since they normally use engine coolant as their heat source.



SLIDE 13

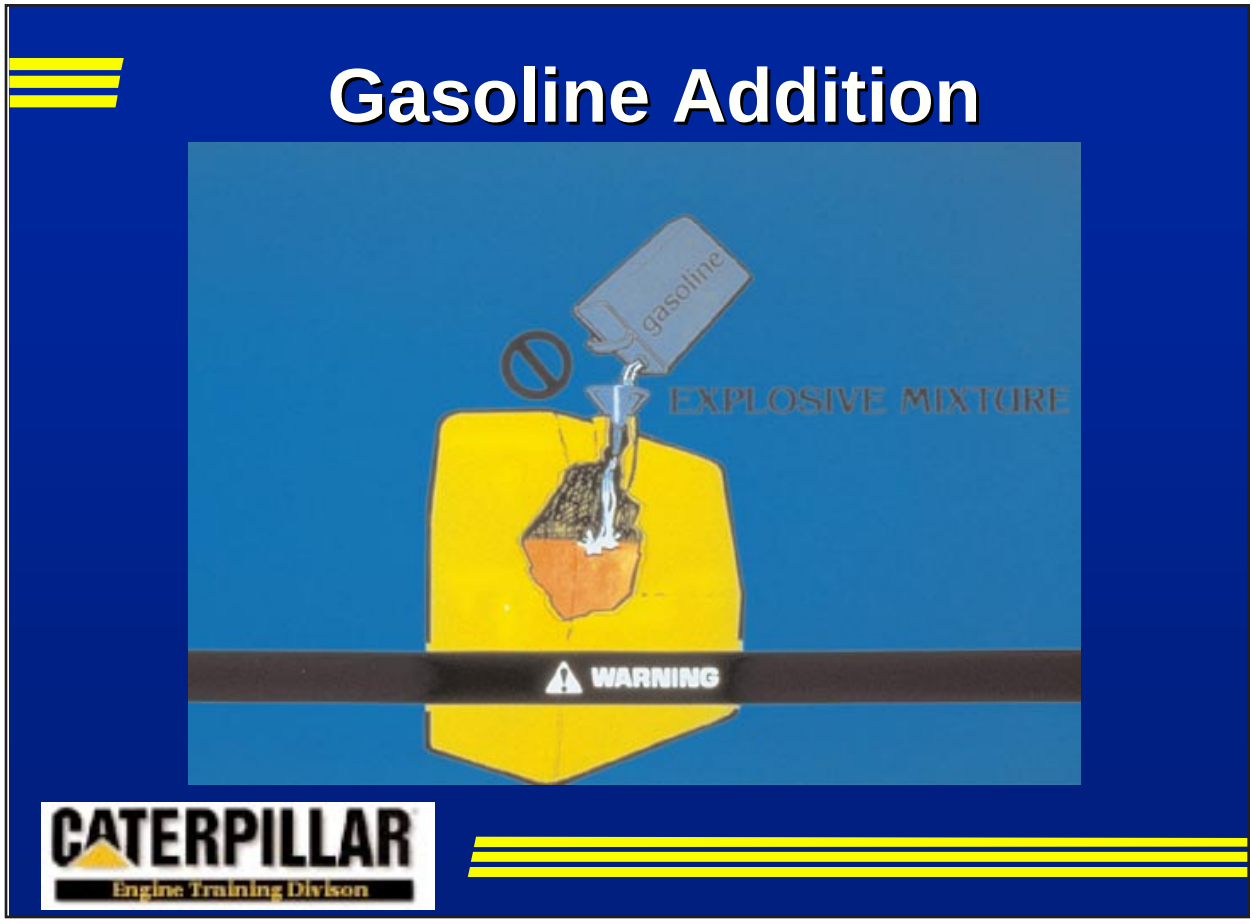
Fuel heaters

Engine performance

Electronic engines will adjust fuel rate

A fuel heater will keep the wax dissolved and permit it to flow through the filters with the fuel. Several types of fuel heaters are available on Caterpillar engines as factory installed options. They can be installed between the fuel filter base and the spin-on filter or between the fuel tank and fuel filter. Most of the heaters use engine coolant to heat the fuel and prevent ice or wax crystal formation in the filter. Fuel heaters should only be used as required, because as fuel temperature rises, engine performance declines. There is approximately a 1% horsepower loss for every 10ºF increase in fuel temperature. Fuel heaters should not be used if the ambient temperature is above 60° F, and the fuel temperature at the outlet of the fuel heater should not be higher than 165ºF.

Some electronic engines will adjust fuel rate depending on fuel temperature. Fuel heaters used on electronic engines should be thermostatically controlled.



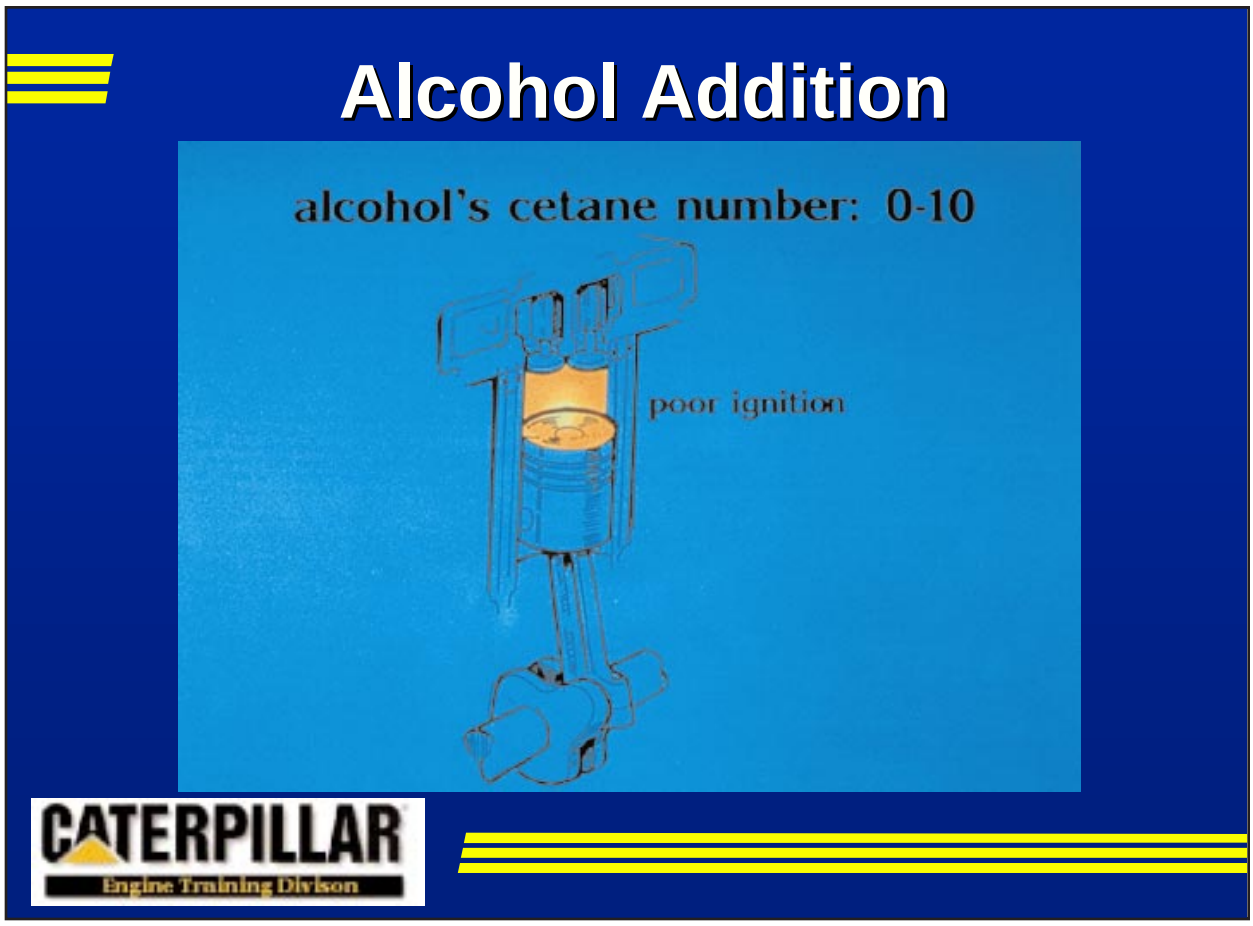
SLIDE 14

Gasoline or naptha

Safety hazard

Evaporation rates

To lower cloud point and pour point temperatures of their fuels, some users blend diesel fuel with gasoline or naphtha. Because of the safety hazard involved, Caterpillar does not recommend that users mix diesel fuel with gasoline or naphtha. Safety practices which may have worked well with pure diesel fuel will not be adequate when dealing with these blends. In a fuel tank, the vapor in the air space above pure diesel fuel is too lean to be a hazard at normal ambient temperatures. Pure gasoline vapors are too rich. However, when diesel fuel is mixed with gasoline or naphtha, the vapor-to-air ratios can be explosive. Caterpillar recommends the other methods already discussed to lower pour point or cloud point temperatures.



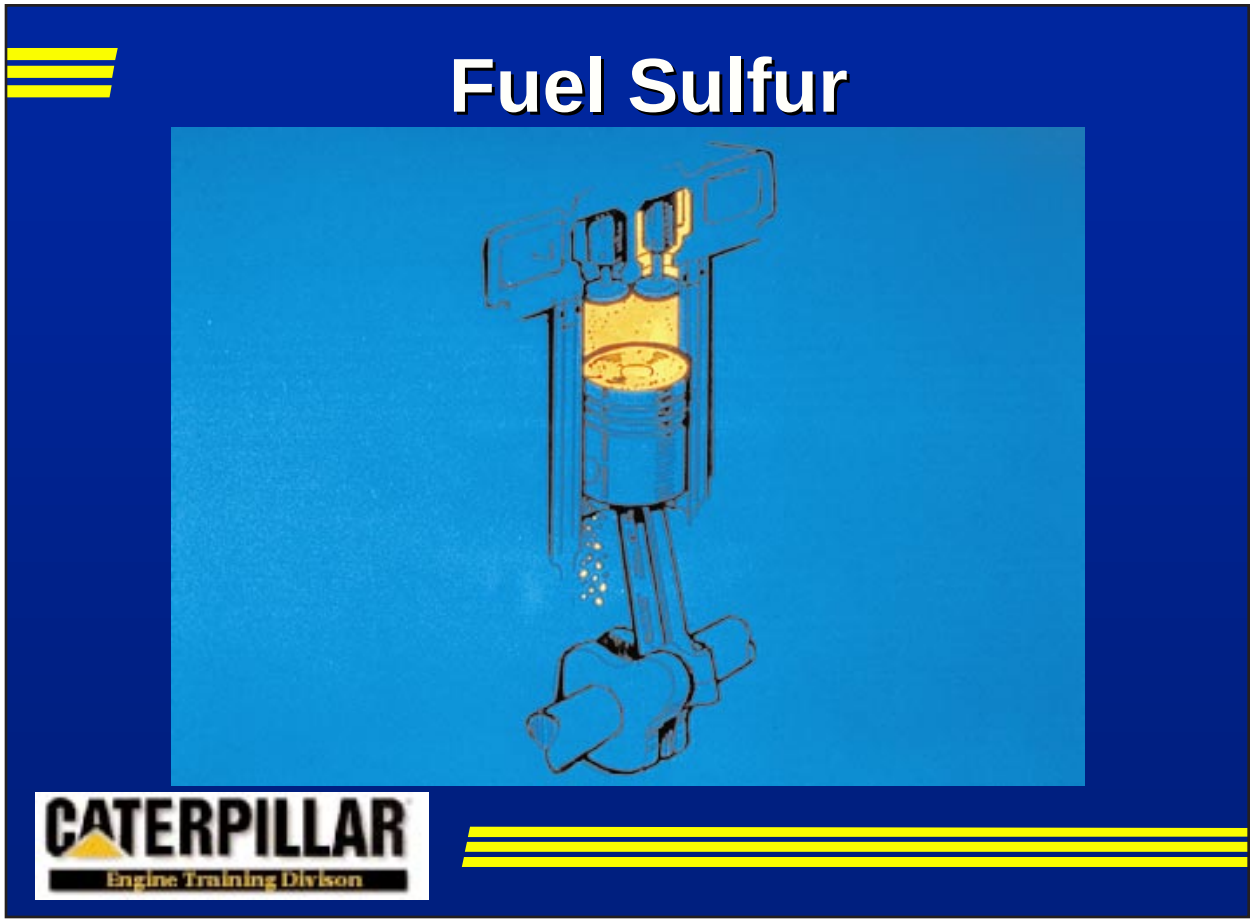
SLIDE 15

Alcohol to adjust pour point and cloud point

Low cetane number

Poor lubricating characteristics

Some users also like to use alcohol to adjust pour and/or cloud point. Alcohol, either methanol or ethanol, has a low cetane number and poor lubricating characteristics. The cetane numbers of ethanol and methanol are similar—in a range of 0 to 10. This means that pure alcohol does not have good ignition characteristics when used in a diesel engine and must be mixed with large quantities of cetane improvement additives which are quite expensive. Also, in current fuel injection systems, the diesel fuel lubricates some of the fuel injection system components. In addition, alcohol does not have good lubrication characteristics.



SLIDE 16

Fuel sulfur

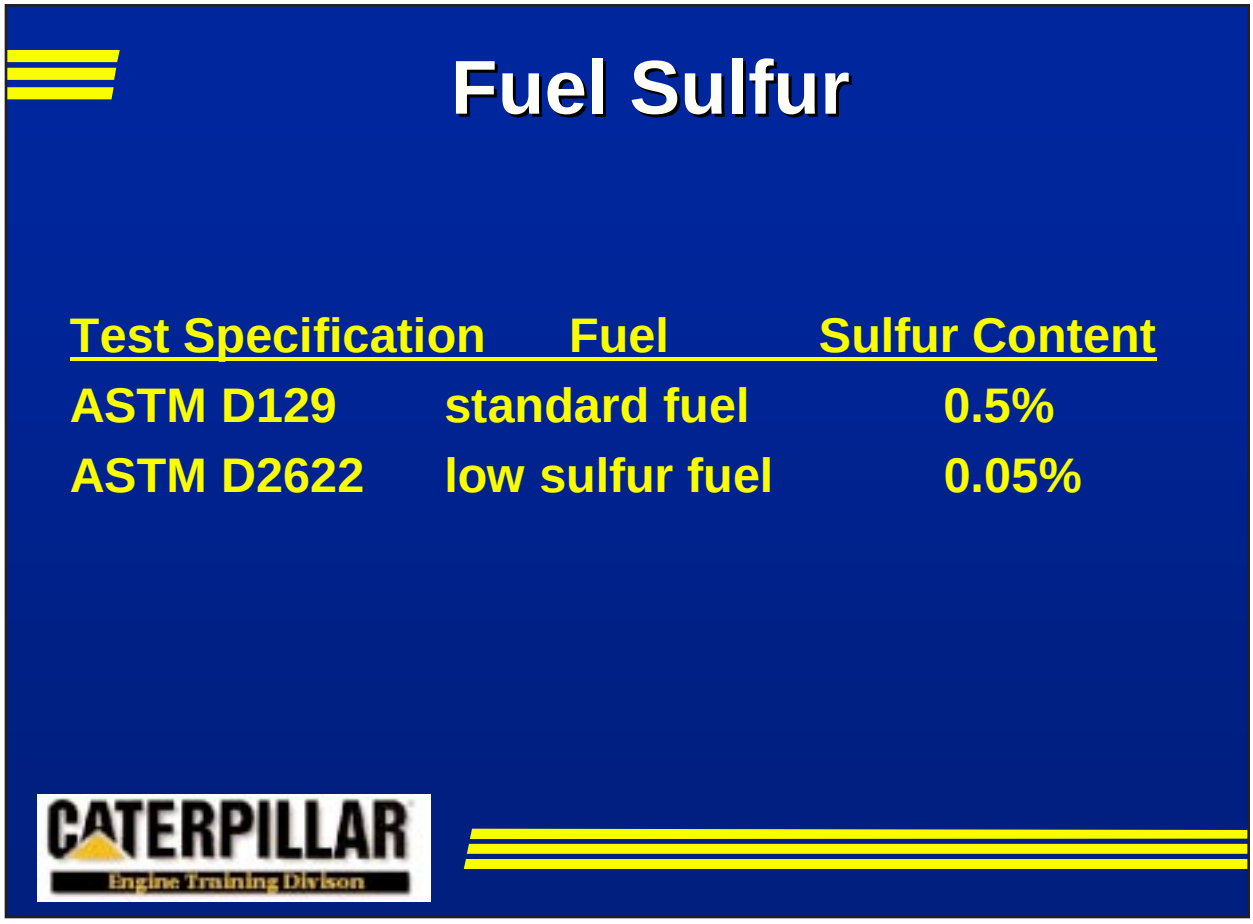
Silent enemy

Oxides of sulfur formed during the combustion process

Acid formation

Corrosive wear

Caterpillar diesel engines have a “silent” enemy within diesel fuel - sulfur. It is called the “silent” enemy because sulfur content does not directly affect engine performance. It has no effect on engine startability or power. Sulfur content doesn’t become a harmful factor until after the fuel has been burned. During the combustion process, sulfur dioxide (SO_2) and sulfur trioxide (SO_3) are formed. These oxides of sulfur combine with the water vapor formed during combustion to create sulfuric acid. This acid causes corrosive wear in engines and increases the chance of early engine failure.



SLIDE 17

Sulfur content

Standard fuel

Low sulfur fuel

In the United States, fuels which meet ASTM specifications for number 1 and number 2 diesel must contain no more than 0.5% sulfur by weight.

Fuels that meet ASTM for low sulfur must contain no more than 0.05% sulfur by weight.

A new fuel specification is now available. This has only 0.015% sulfur by weight and will be required for on-highway engines in about 2007.

This does not mean that every fuel will meet this specification. In fact, fuels with sulfur content in excess of 0.5% have regularly been found in field surveys.

Caterpillar engines can burn these higher sulfur fuels. However, to use fuels with sulfur content greater than 0.5%, you have to take extra precautions to protect the engine from corrosive wear.

SLIDE 18

Fuel selection is important

Clean fuel meeting Caterpillar's fuel recommendations promotes maximum engine service life and performance. Anything less is a compromise and the risk is the user's responsibility. Dirty fuels and fuels not meeting Caterpillar's minimum fuel specifications will adversely affect engine performance and will shorten engine life. It is good economics to carefully consider fuel selection.

Small Engine Fuel Systems

Lesson Plan 3 - Fuel Related Problems

Objectives:

- The student will be able to demonstrate the ability to measure fuel API when given a sample in a lab exercise and convert non standard readings to standard with at least 70% accuracy on a written test.
- The student will be able to calculate specific weight of a fuel with at least 70% accuracy on a written test.
- The student will be able to calculate expected horsepower loss or gain due to fuel API with at least 70% accuracy on a written test.
- The student will be able to explain operation of a fuel sight glass with at least 70% accuracy on a written test.
- The student will be able to explain the use of various fuel heaters, and Caterpillar's stance on methods of mixing oil and fuel with at least 70% accuracy on a written test.

Literature Needed:

Diesel Fuel and Your Engine	SEBD0717
Engine Performance Reference	LEXT1044
Blending Used Crankcase Oil	LEKQ6070
Blending Used Crankcase Oil for use with Cat HD Diesel Engines	LEKQ6071

Hardware Needed:

Chalk/White board

1P7408 Thermo-hydrometer

5P2712 Thermo-hydrometer

1P7438 Beakers

Various fuel samples

Time Required:

1 Hour

Tasks Required by Instructor to Meet Objectives:

1. Using “Diesel Fuels and Your Engine” SEBD0717, Emphasize the following points:
   A. How fuel quality relates to power complaints.
   B. Explain fuel API, specific gravity and density. (See page 6 of Diesel Fuel and Your Engine)
      1. Explain the method of using a thermo-hydrometer
      2. Explain the fuel meniscus
   C. Converting fuel API degrees to specific weight. (See page 7 of Diesel Fuel and Your Engine)
2. Using Horsepower Correction Factors, emphasize the following points:
   A. Pass various fuel samples around the room. Have the students find the measured API and temperature of each sample. Write these findings on the board
   B. Using the fuel API correction chart have the students find the corrected fuel API at 60 degrees F. Add these finding to the data on the board.
   C. Using fuel density correction factors, assess how each of the samples would affect performance.
      1. Find the correction factor for each of the samples and add this to the information on the board.
      2. Find the corrected power for each of the samples for a 3126E 300 hp @ 2200 rpm.
         a. To fine the corrected hp, divide the advertised power by the correction factor.
         b. The operator would feel it only if we find a hp change of greater than 15 hp.
3. Using "Blending Used Crankcase Oil with Diesel Fuel" LEKQ6070, and Blending Used Crankcase Oil with Diesel Fuel for use with Caterpillar Heavy Duty Diesel Engines “ LEKQ6071 emphasize that blending used oil with diesel fuel is permissible in some applications, but will affect emissions.

SMALL ENGINE FUEL SYSTEMS

Lesson Plan 4 - Basic Governor Theory

Objectives:

- The student will be able to explain the function of the major components of a governor with at least 70% accuracy on a written test.
- The student will be able to explain the relationship between the flyweights and governor spring with at least 70% accuracy on a written test.

Literature Needed:

Basic Governor Theory Slide Script Copy

Hardware Needed:

Slide Projector

Screen

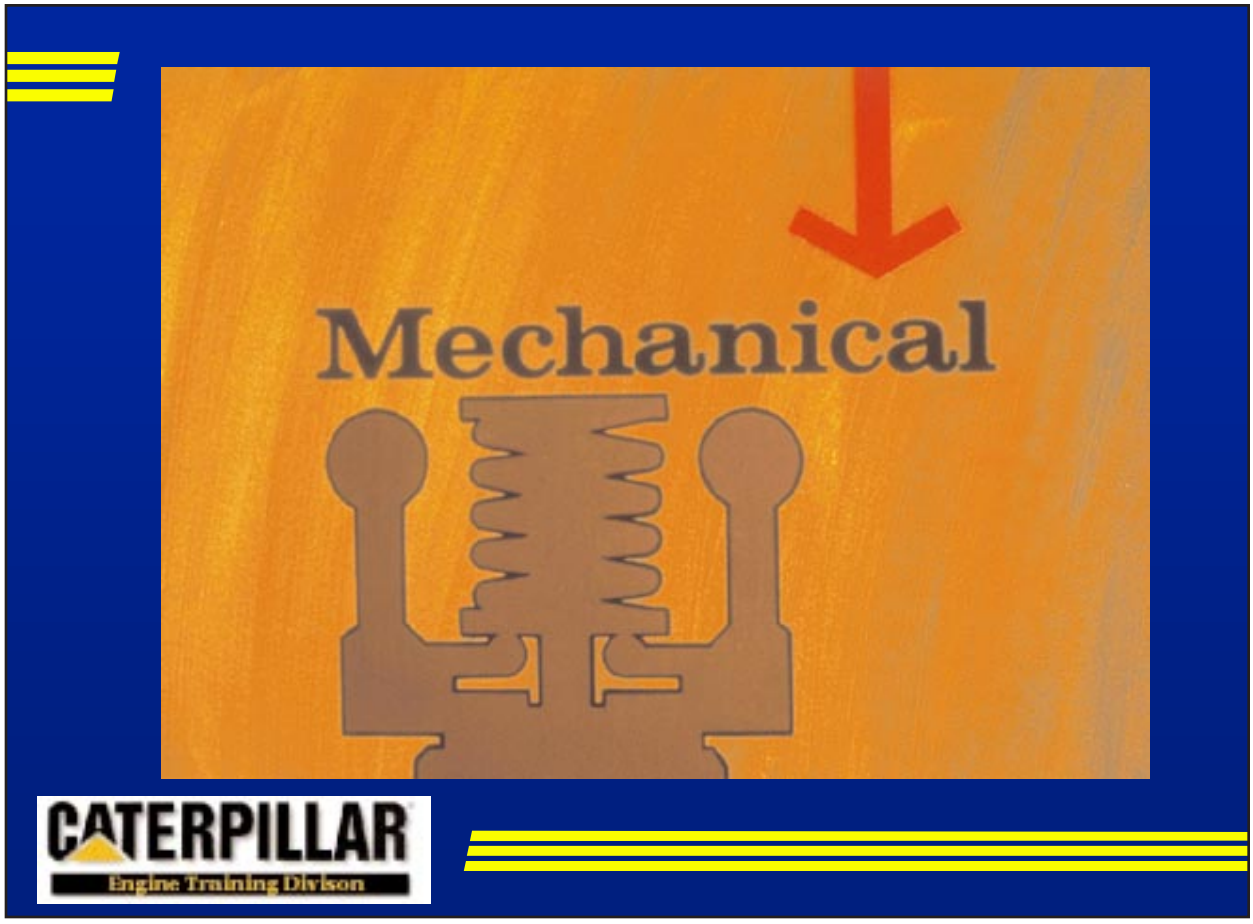
Basic Governor Slides

Time Required:

0.25 Hours

Tasks Required by Instructor to Meet Objectives:

1. Review the slides and emphasize the following points:
   A. Speed measuring mechanism
   B. Fuel changing mechanism
   C. High and low idle screws
   D. Rack limiting devices
2. Emphasize the importance of always having a governor in control when operating an engine.



SLIDE 19

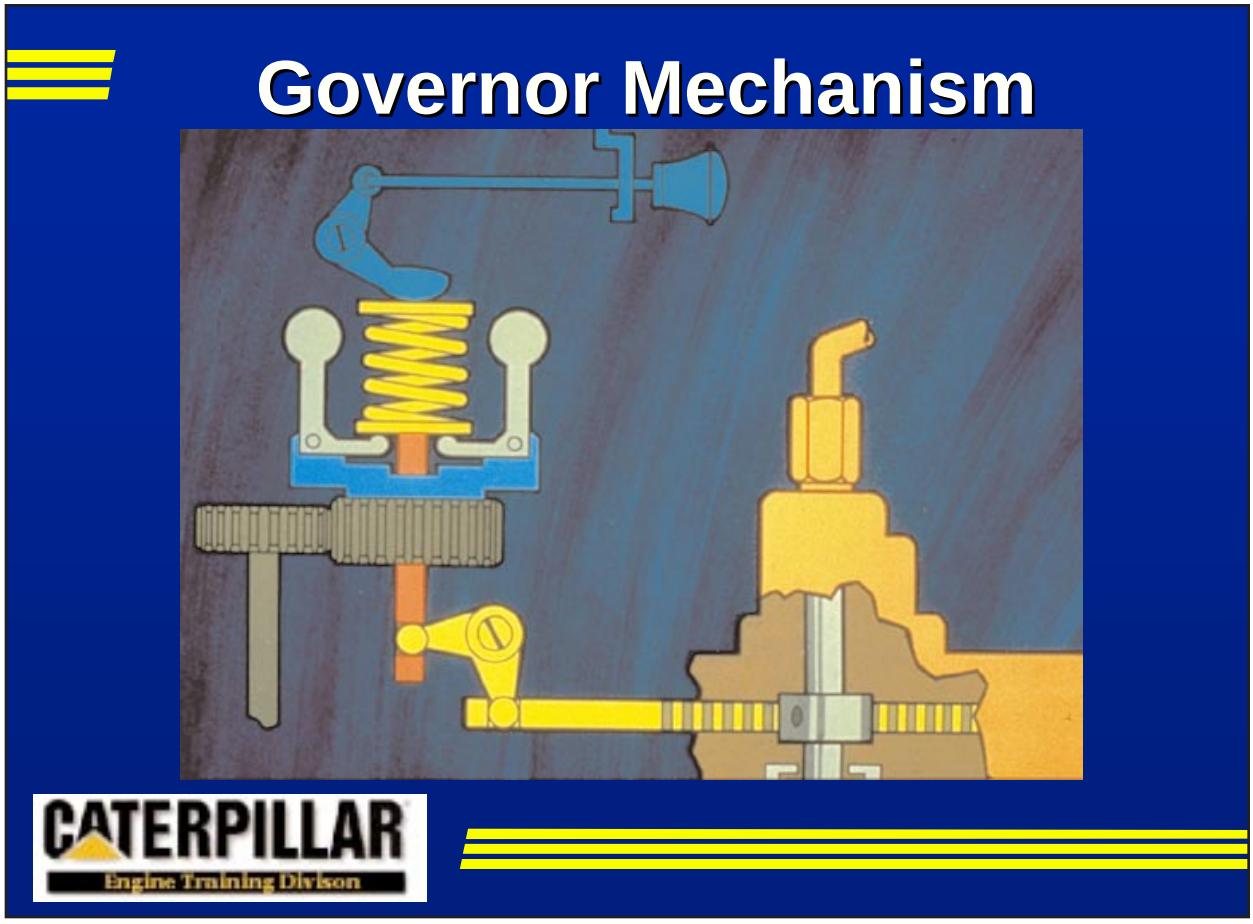
Mechanical governors

This presentation introduces and explains basic operation of the mechanical governor. The mechanical governor is the simplest of the various types of governors and is basic to their operation. Besides the mechanical governor, Caterpillar engines use servo-mechanical governors, hydraulic governors and electronic governors.

SLIDE 20

Never operate a diesel engine without a governor controlling it.

Never operate a diesel engine without a governor controlling it. If you were to move the fuel rack of a diesel engine to the full “ON” position without a load, with the governor not connected, the engine speed might climb and exceed safe operating limits before you could shut it down. One second...two seconds...before you knew what was happening, the engine may have been seriously damaged by overspeeding. This warning - “never operate a diesel engine without a governor controlling it” - is concerned with one of the purposes of governors: to prevent engine overspeeding. Governors also keep the engine at the desired speed and increase or decrease engine power output to meet load changes.



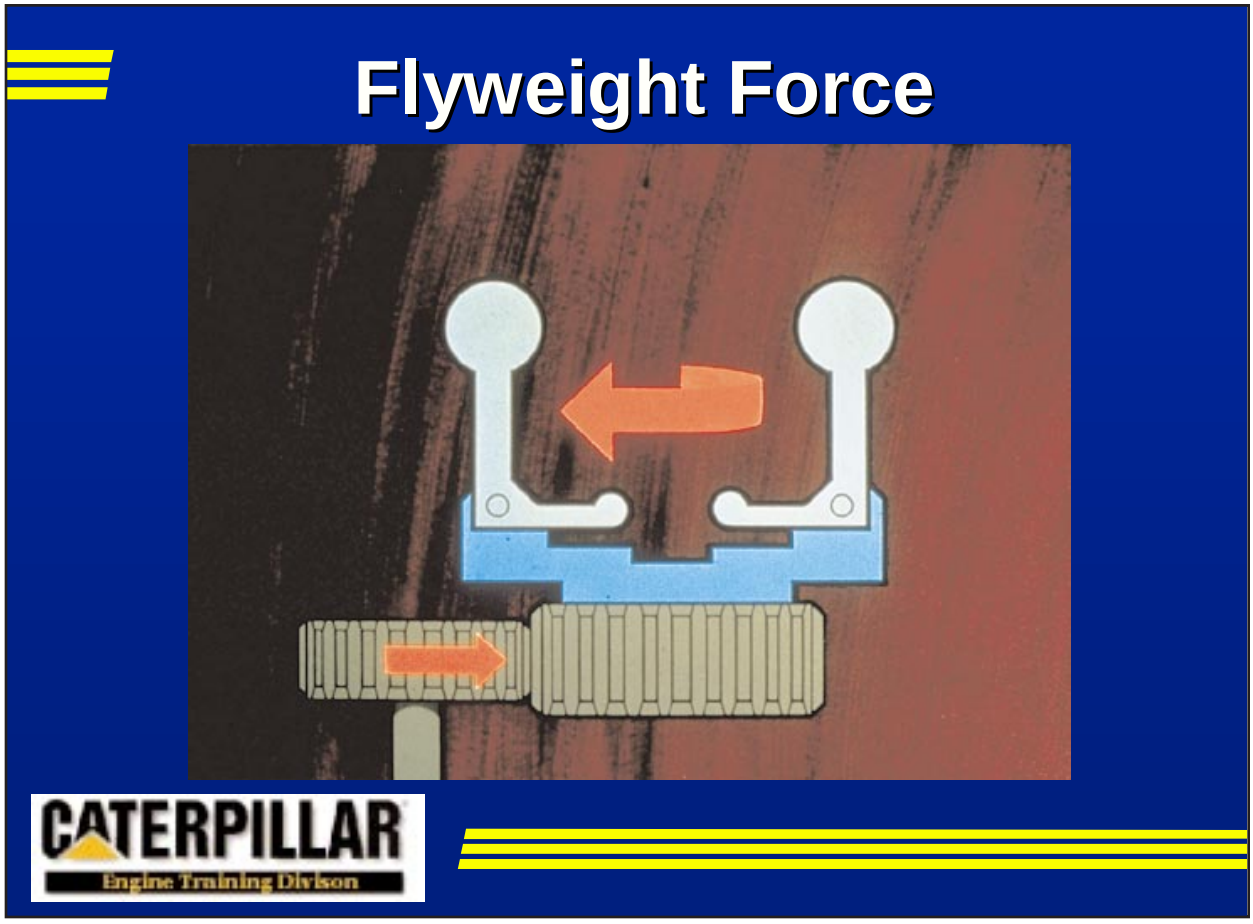
SLIDE 21

Two basic mechanisms

Speed measuring

Fuel changing

Diesel engine mechanical governors consist of two basic mechanisms: the speed measuring mechanism and the fuel changing mechanism.



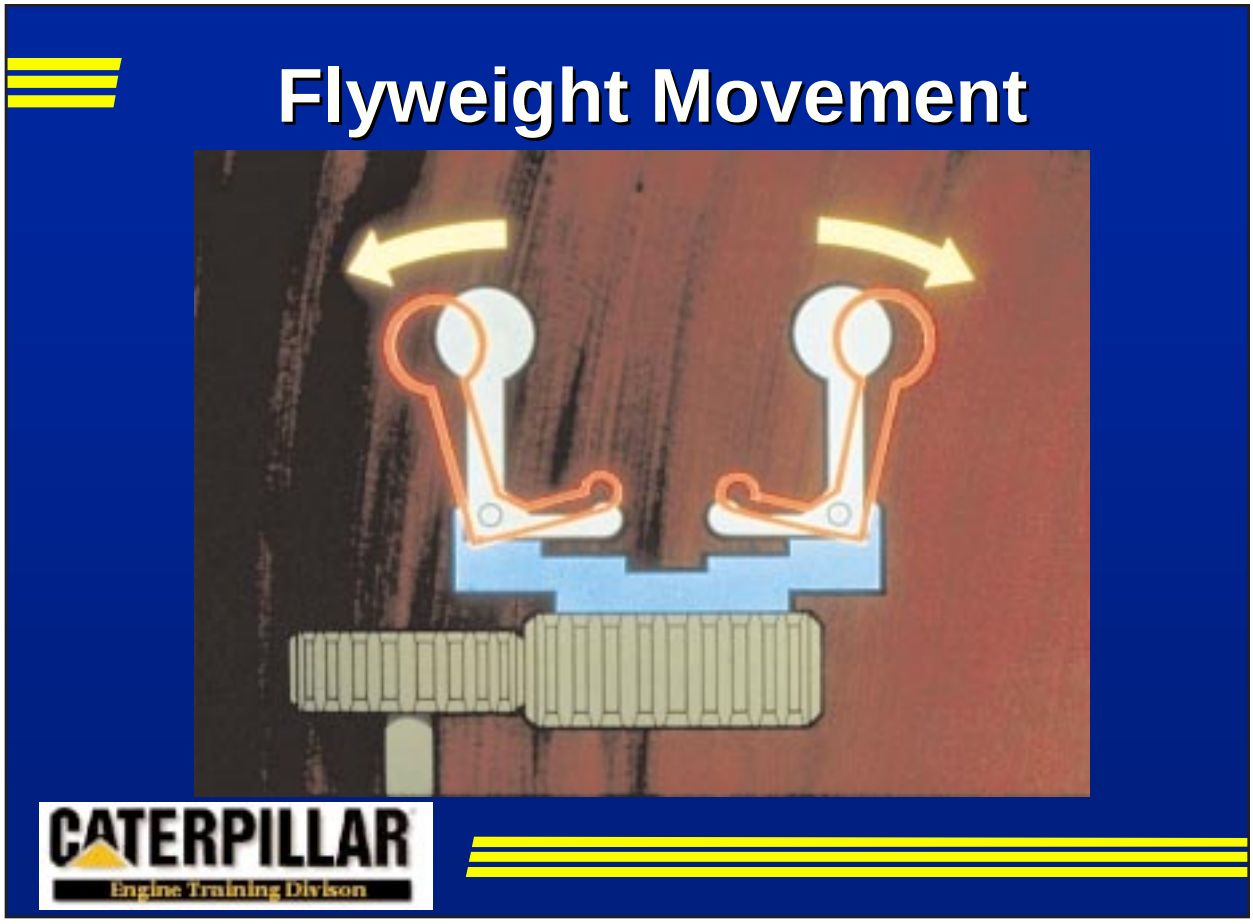
SLIDE 22

Speed measuring

Flyweights

Ball arms

The speed measuring mechanism is simple, has few moving parts and measures engine speed accurately. The flyweights and “L” shaped ball arms which pivot are mounted on the governor drive. As the engine rotates, the flyweights rotate.



SLIDE 23

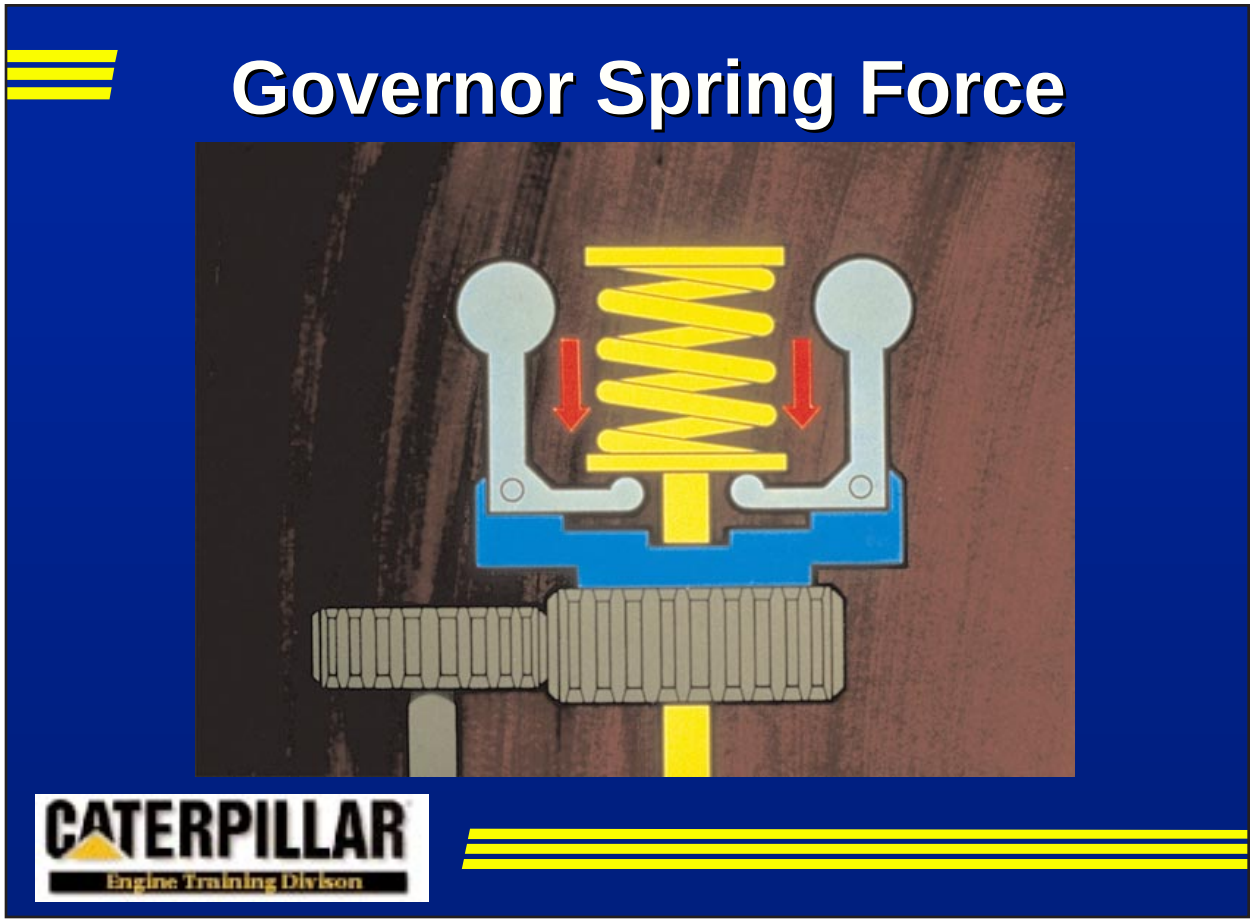
Flyweights rotate

Centrifugal force

Speed change

Fuel off direction

As the flyweights rotate, they exert a centrifugal force outward. The flyweights move outward pivoting the ball arms upward. The amount of outward force depends on the speed of rotation. Centrifugal force is the basic operating principle of the speed measuring mechanism. Now, what is centrifugal force? If we tie a ball on a string and swing it around and around, the faster it goes, the more centrifugal force (outward force) is exerted on the ball. This centrifugal force swings the ball outward and upward until the ball is nearly straight out. We can see that the faster we swing it, the greater the pull on the string and the farther outward it swings. Increasing the centrifugal force of the flyweights in the governor will move the rack in the fuel off direction.

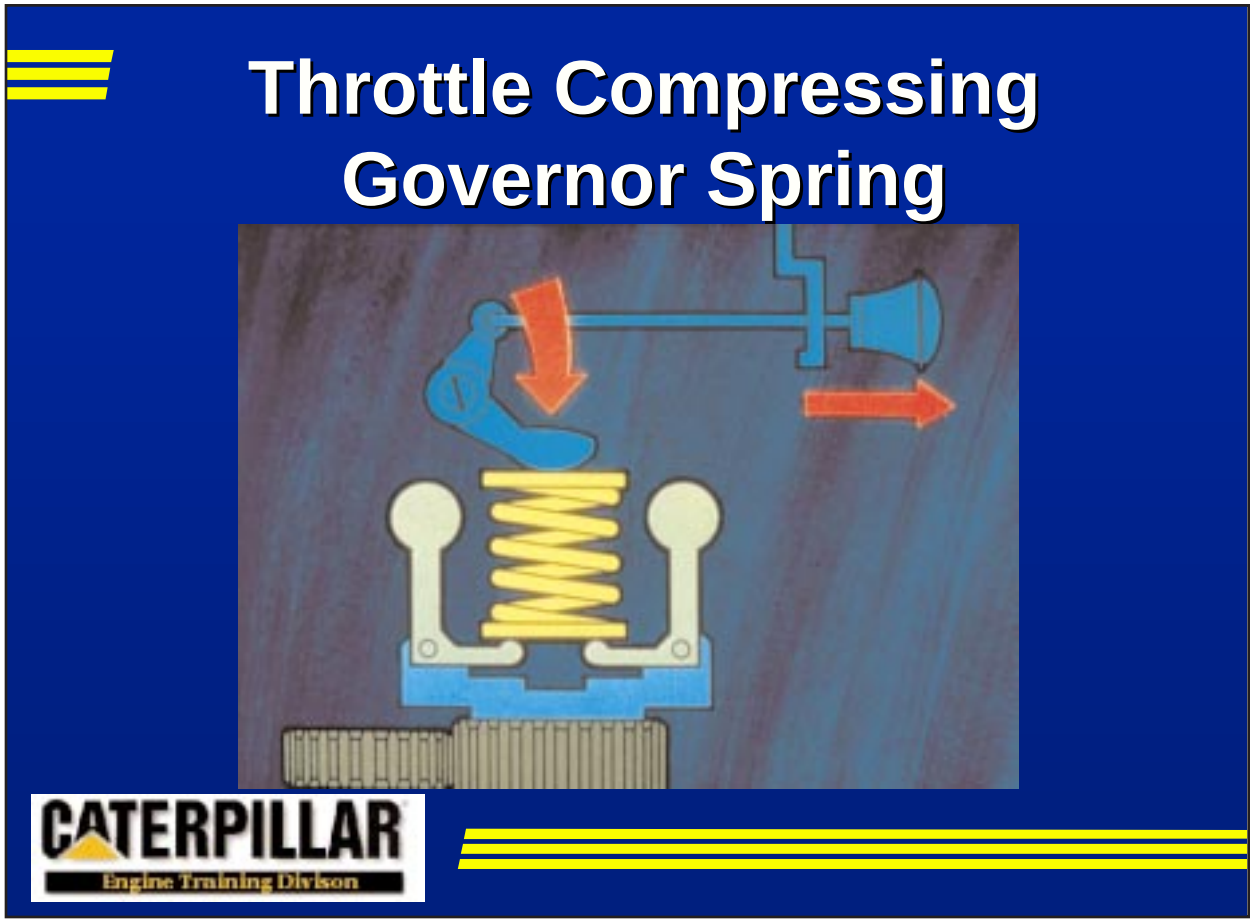


SLIDE 24

Governor spring

Fuel on direction

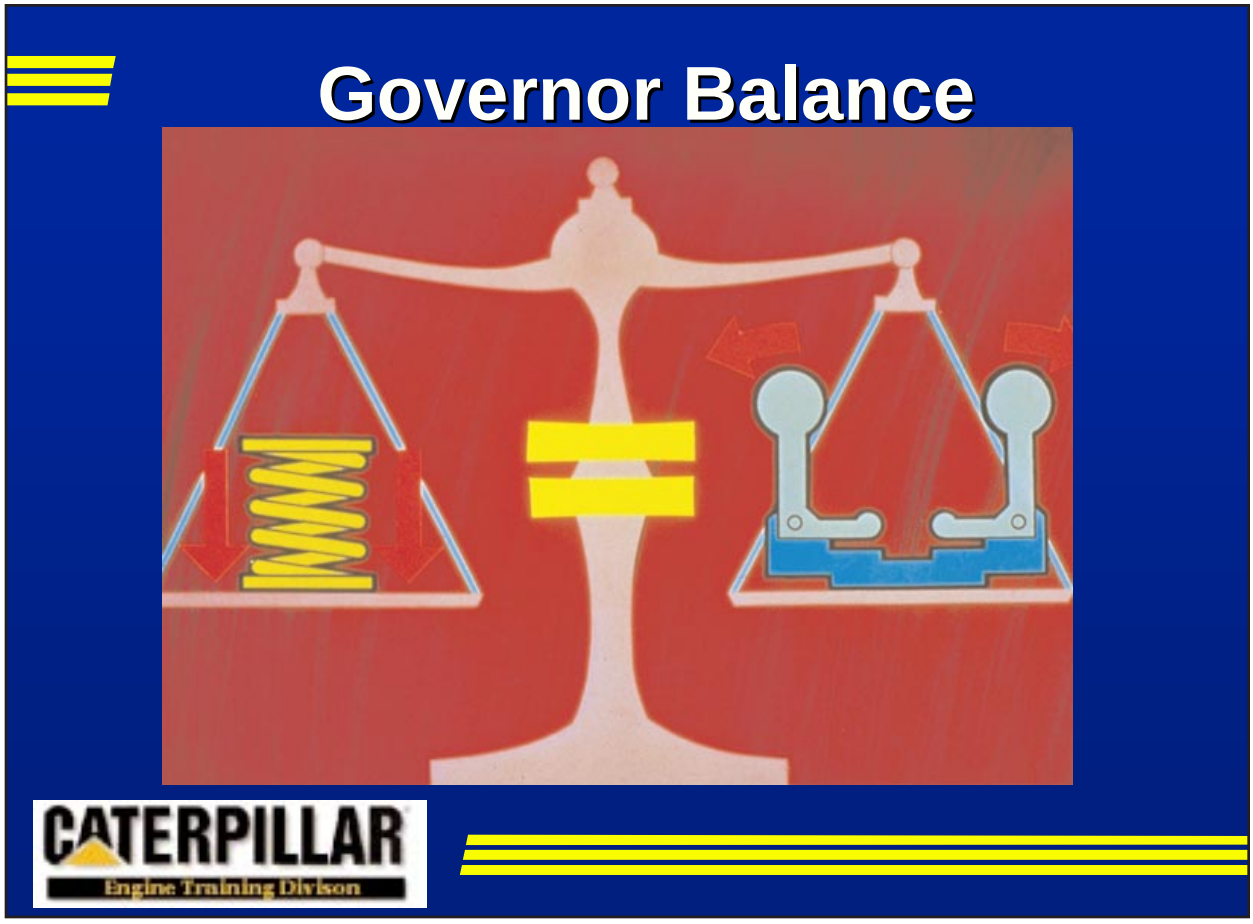
We need to control this centrifugal force, so we have the governor spring. The spring acts against the force of the rotating flyweights and tends to oppose them. The force exerted by the spring depends on the governor control setting. Increasing the force applied to the governor spring will move the rack in the fuel on direction.



SLIDE 25

Governor control lever

A lever connected to the governor control (throttle) pushes on or compresses the spring. The spring force opposes the flyweights to regulate the desired engine speed setting. The governor control, shown here as a simple push-pull knob, may be a hand operated control or a foot operated accelerator pedal.

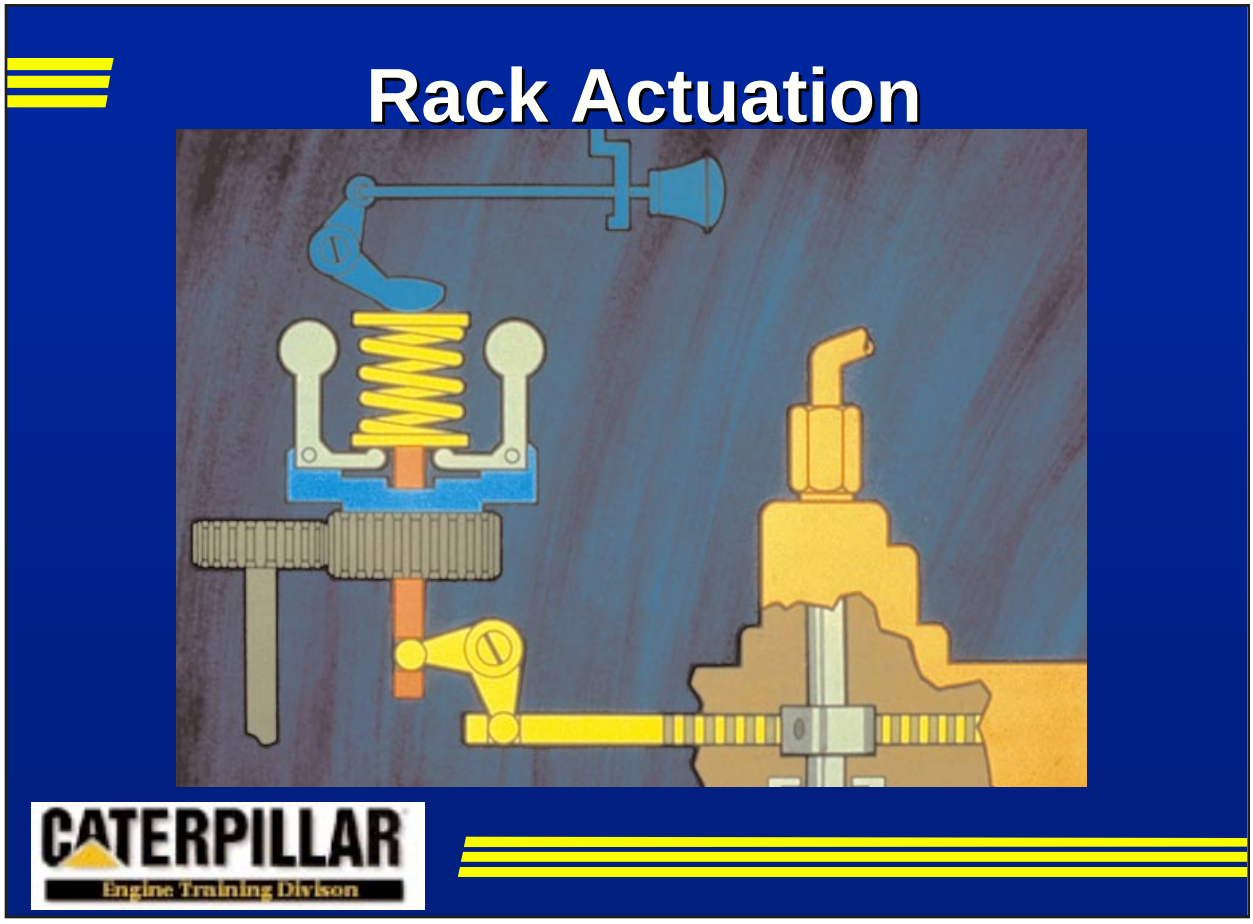


SLIDE 26

Spring force equals the centrifugal force of the flyweights

Constant speed

As long as the spring force equals the flyweight centrifugal force, the engine speed remains constant.



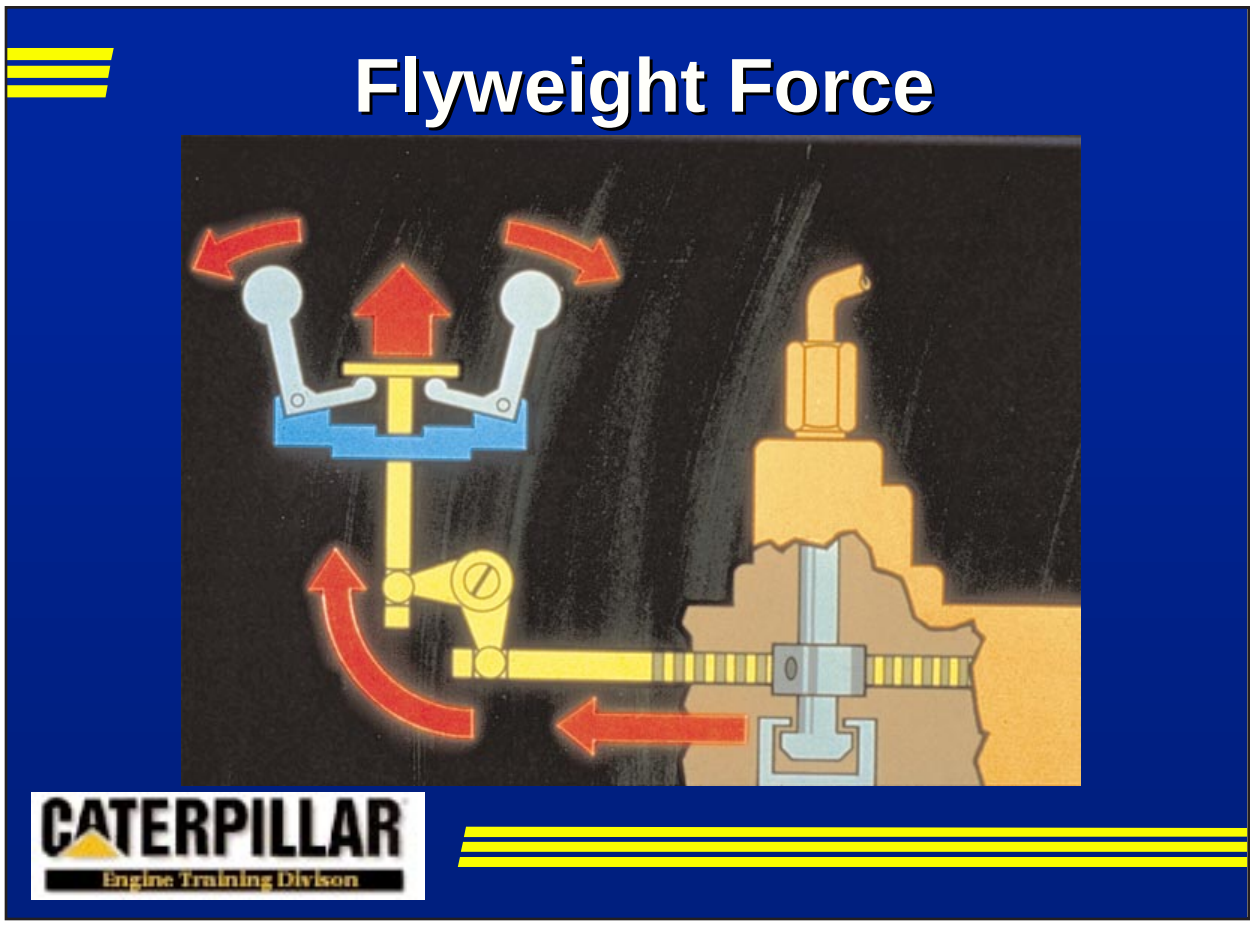
SLIDE 27

Speed measuring mechanism

Fuel changing mechanism

Link to fuel injection pump

The speed measuring mechanism senses and measures engine speed changes. The fuel changing mechanism links the speed measuring mechanism with the fuel injection pumps to control fuel and with that the engine speed.



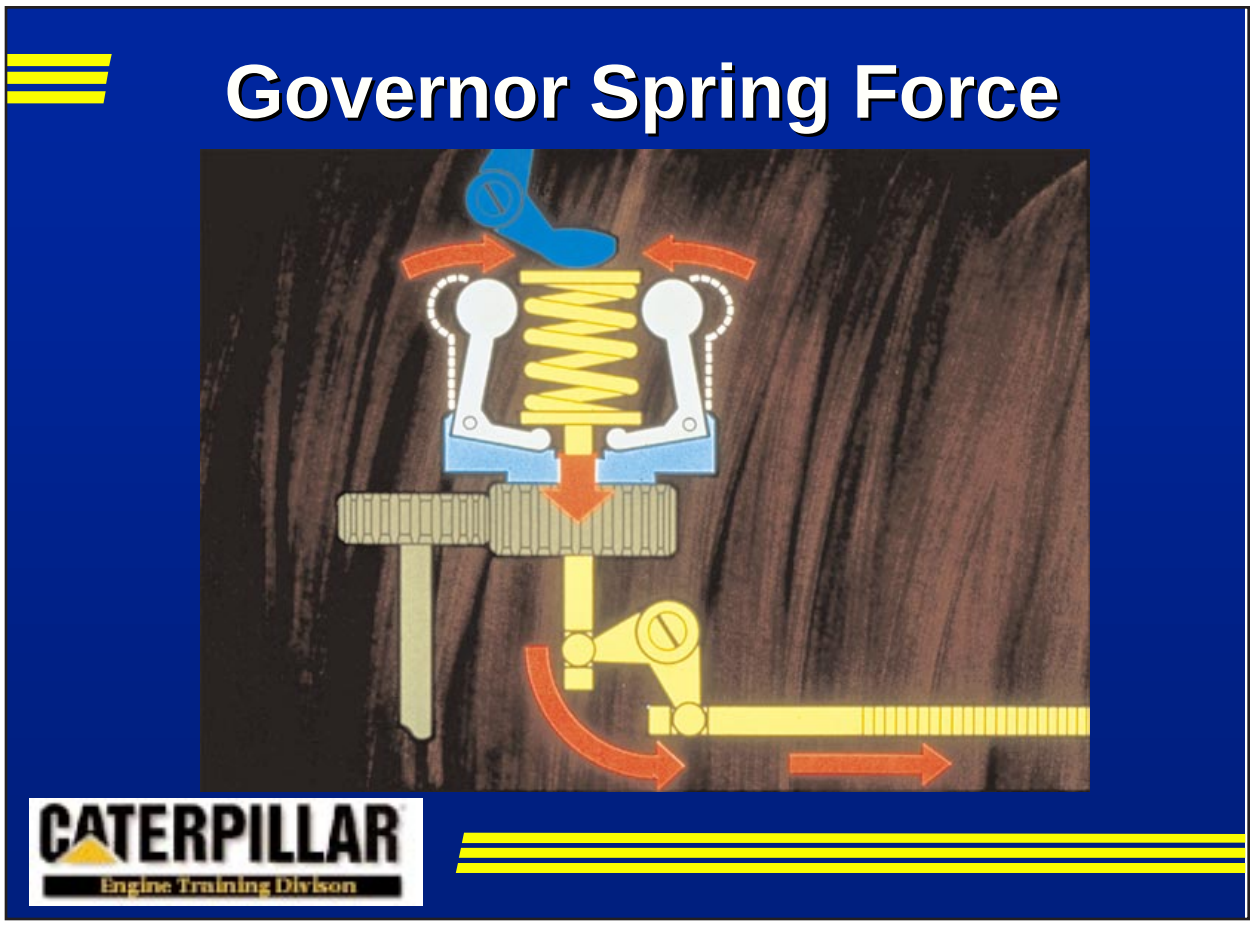
SLIDE 28

Speed increase

Simple linkage

Injection duration

As the engine speed increases, the flyweights will move outward. This movement is transferred through a simple linkage to the rack and, therefore, to the fuel injection pump plunger rotating it to change (decrease) injection duration.



SLIDE 29

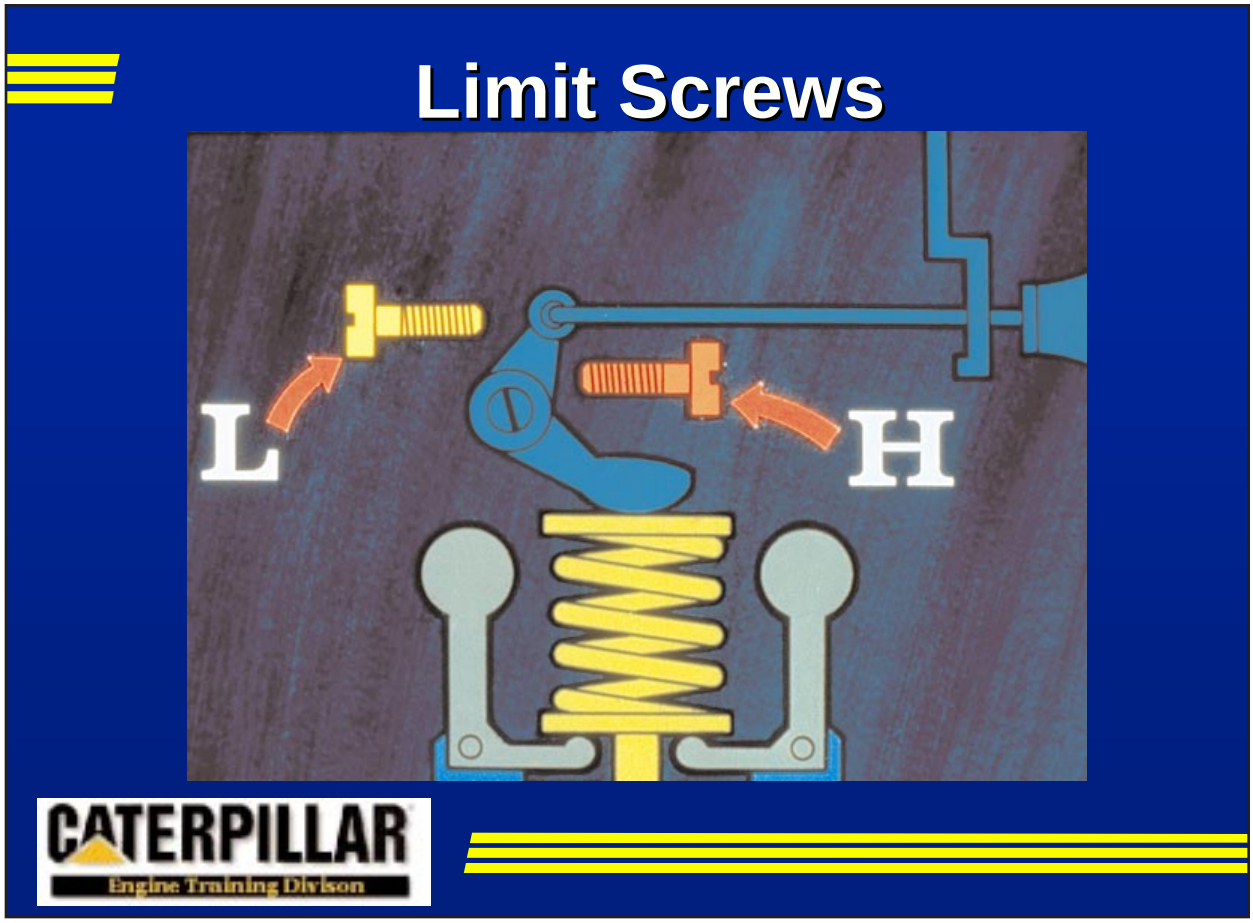
Engine load increases

Engine speed decreases

Flyweight force

Rack position

When the engine load increases, as when a truck starts up a hill, the engine speed decreases. Due to the slower engine speed, the flyweight force decreases, and the spring moves the linkage and rack to increase the fuel to the engine. The increased fuel position is held until the engine speed returns to the desired setting, and the flyweight force again balances the spring force.



SLIDE 30

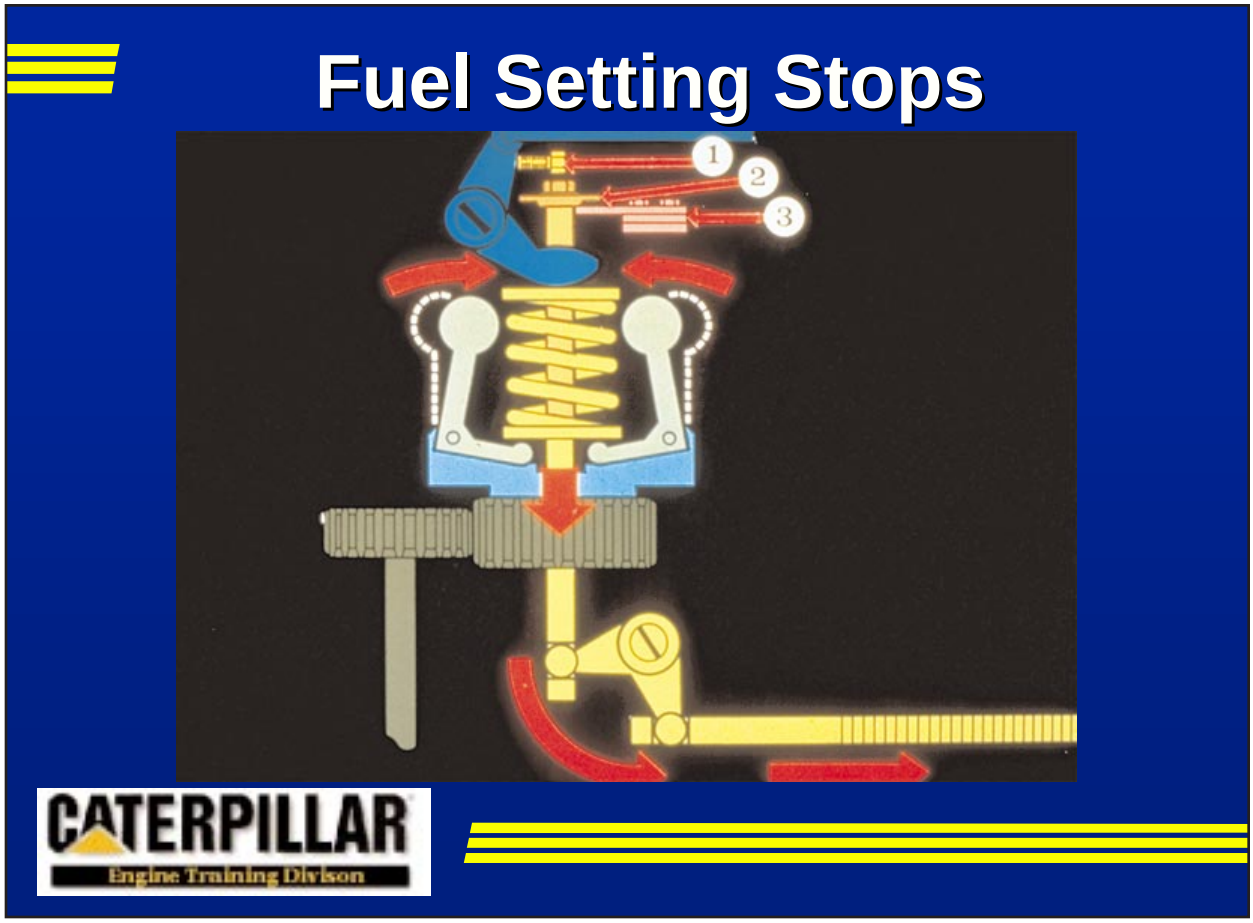
Low Idle

High Idle

RPM Settings

Governor Spring Force Settings

Two adjusting screws limit the travel of the governor control lever between the LOW IDLE position and the HIGH IDLE position. The low idle stop and high idle stop are simply minimum and maximum engine rpm setting with no load on the engine. Althought the result is engine rpm, the function of the screws would be minimum and maximum governor spring deflection giving us minimum and maximum governor spring force.



SLIDE 31

High idle

Increased load

Speed changes

Collar

Stop bar

Full load

Never operate a diesel engine without a governor controlling it

When the engine is operating with the governor at high idle (1) and picks up a load, the engine speed decreases and the flyweight centrifugal force lessens. The governor spring moves the rack to give the engine more fuel and increases power.

The collar (2) and stop bar (3) limit the distance the spring can move the rack. As the collar contacts the stop bar, full load position is reached. This limits the maximum amount of fuel delivered to the engine so as not to exceed design limitations.

In conclusion, it must always be remembered that a governor is capable of reacting faster than we can, so never operate a diesel engine without a governor controlling it.

Small Engine Fuel Systems

Lesson Plan 5 - Performance Curves

Objectives:

- The student, with at least 70% accuracy on a written test, will be able to explain high idle, full load/governed, set point, governor overrun, overspeed, lug, horsepower, rack position, torque, torque rise, fuel consumption, and boost.
- The student will be able to calculate horsepower, torque, torque rise, fuel consumption and percent overrun with at least 70% accuracy on a written test.

Literature Needed:

Power Curve Slide Script	Copy
Engine Performance Reference	LEXT1044

Hardware Needed:

Power Curve Slides

Projector

Screen

Chalk and Chalkboard

Calculator

Time Required:

2 Hours

Tasks Required by Instructor to Meet Objectives:

1. Using a tent curve on the chalkboard or the slides, discuss the following subjects:
   A. High Idle - place 2262 as measured high idle. - State that 2321 was the high idle found on the engine data plate.
      1. High idle shown on the data plate is a bare engine high idle. This has a tolerance of +40/-80 rpm to achieve proper set point.
      2. High idle is not a setting spec. It is used to adjust set point when the rack setting is correct.
      3. High idle on an electronic engine is rated plus 20 rpm.

B. Full Load (Rated/Governed)

1. Point where the rack screw is first in full contact with the torque spring on all engines except electronic engines.
2. Point where all governed specs are achieved.

C. Set Point

1. On those engines that have it, is the governor position where the rack screw is in contact with the torque spring between 10-45%.
2. Governed occurs 20 rpm below set point.
3. Set point is controlled by two features:
   a. FLS
   b. High Idle

D. Rack Curve

1. Overrun/droop curve
2. FLS
3. FTS

E. Horsepower Curve

1. Explain the reasons for the shape of the curve.
   a. Full load/governed - Insert 2100 rpm as governed speed on curve.
   b. Peak horsepower
   c. Peak torque horsepower
2. Explain the relationships to horsepower
   a. Rack - after we get into lug below FTS, injection volume remains the same, but fewer injections occur, therefore fuel rate lowers.
   b. Fuel rate - horsepower curve is established by fuel rate curve.
   c. Boost - normally follows the same curve as fuel rate except when a waste gate turbo is installed.
      1. Waste gate provides increased boost at low rpm.
      2. Waste gate limits peak boost to control BMEP.
      3. Clamping the waste gate hose is cause for warranty revocation

F. Torque Curve

1. Full load/governed torque
2. Peak torque
3. Explain the relationship between horsepower and torque
    a. Torque is the twisting force coming from the engine's crankshaft that produces the work.
    b. Horsepower is a calculation that can't even be measured on a dynomometer. We must measure either torque or fuel rate and calculate horsepower from that data.
4. Explain the relationship between horsepower and torque.
    a. As the engine slows, the piston stays in the effective burn window longer providing more time to convert the BTU energy in the fuel to BTU energy of torque.
    b. Also as the engine slows, the internal parasitic loads lower. The energy used to overcome these now go to the flywheel.

F. Calculations - Place 1000 #' @ 2100 (governed) and 1400#' @ 1200 (peak torque)

1. Horsepower - Calucalate at both governed and peak torque. - Show we have 20% loss in power between governed and peak torque.

    Governed

    hp = t X rpm / 5252

    400 hp = 1000 X 2100 / 5252

    Peak Torque

    320 hp = 1400 X 1200 / 5252

2. Torque Rise - Calculate torque rise and show while we have lost 20% power therefore about 20% fuel, the actual pulling force (torque) has risen to 140%.

    %TR = (PT - GT / GT) X 100

    40% = (1400 -1000 / 1000) X 100

3. Droop/Overrun - Typical droop percents are as follows:
    a. Truck - 7 to 10 %
    b. Marine/Vehicular/Industrial - 5 to 7%
    c. Generator Set - 0 to 3%

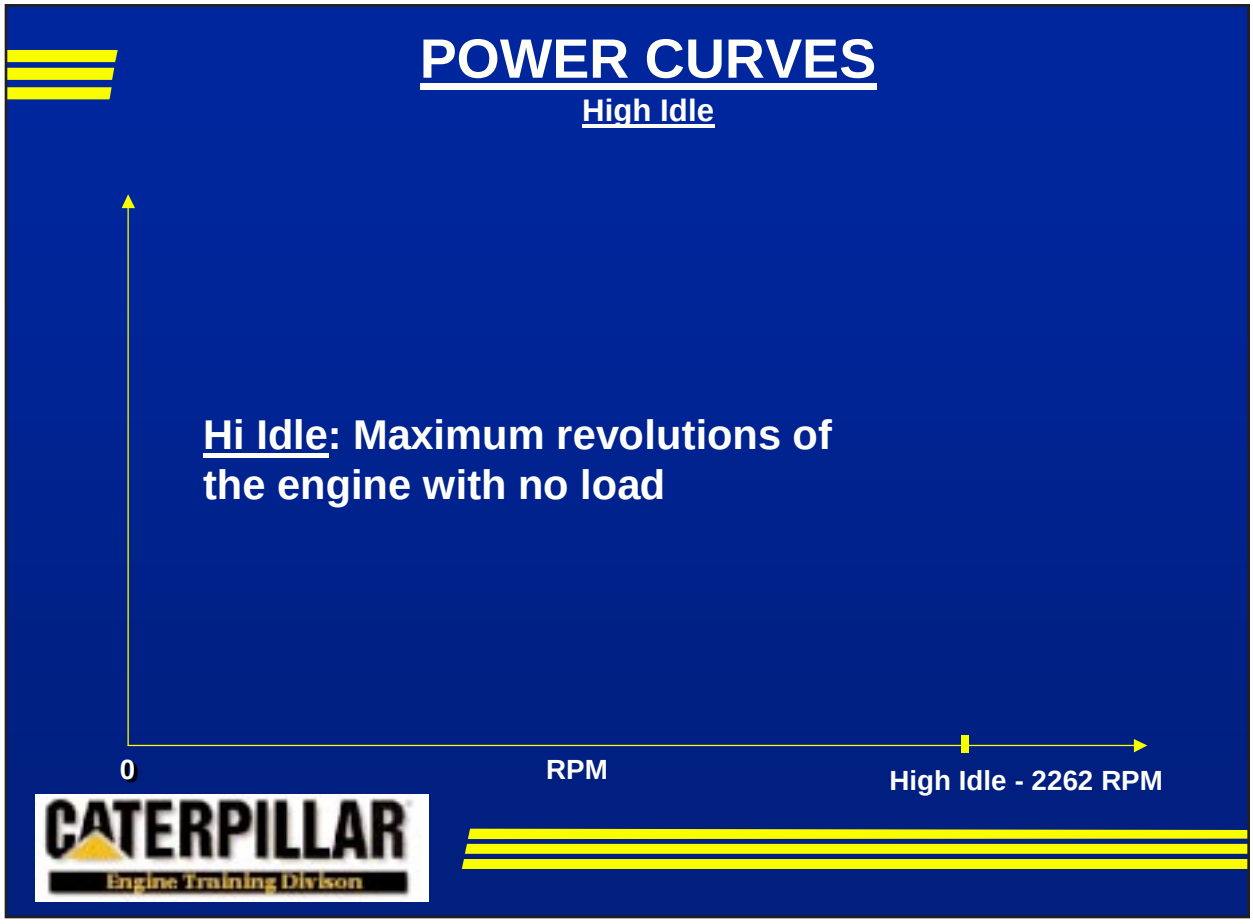
%DR = (HI - Gov / Gov) X 100

7.7% = (2262 -2100 / 2100) X 100

G. Fuel consumption

1. BSFC - Brake Specific Fuel Consumption - The pounds of fuel required to produce one horsepower for one hour.
    a. BSFC published in sales literature are only full load BSFC.
    b. Best BSFC usually occurs below full load speed due to improved efficiencies in the engine.
    c. It is best to run part throttle, if possible, for better fuel economy.
2. Fuel Rate - Measured in gallons per hour.
    a. Fuel rates published in sales literature is only full load rates.
    b. Fuel rate = BSFC X hp / Fuel Density (pounds per gallon)

2. Answer any questions the students have about performance curves.

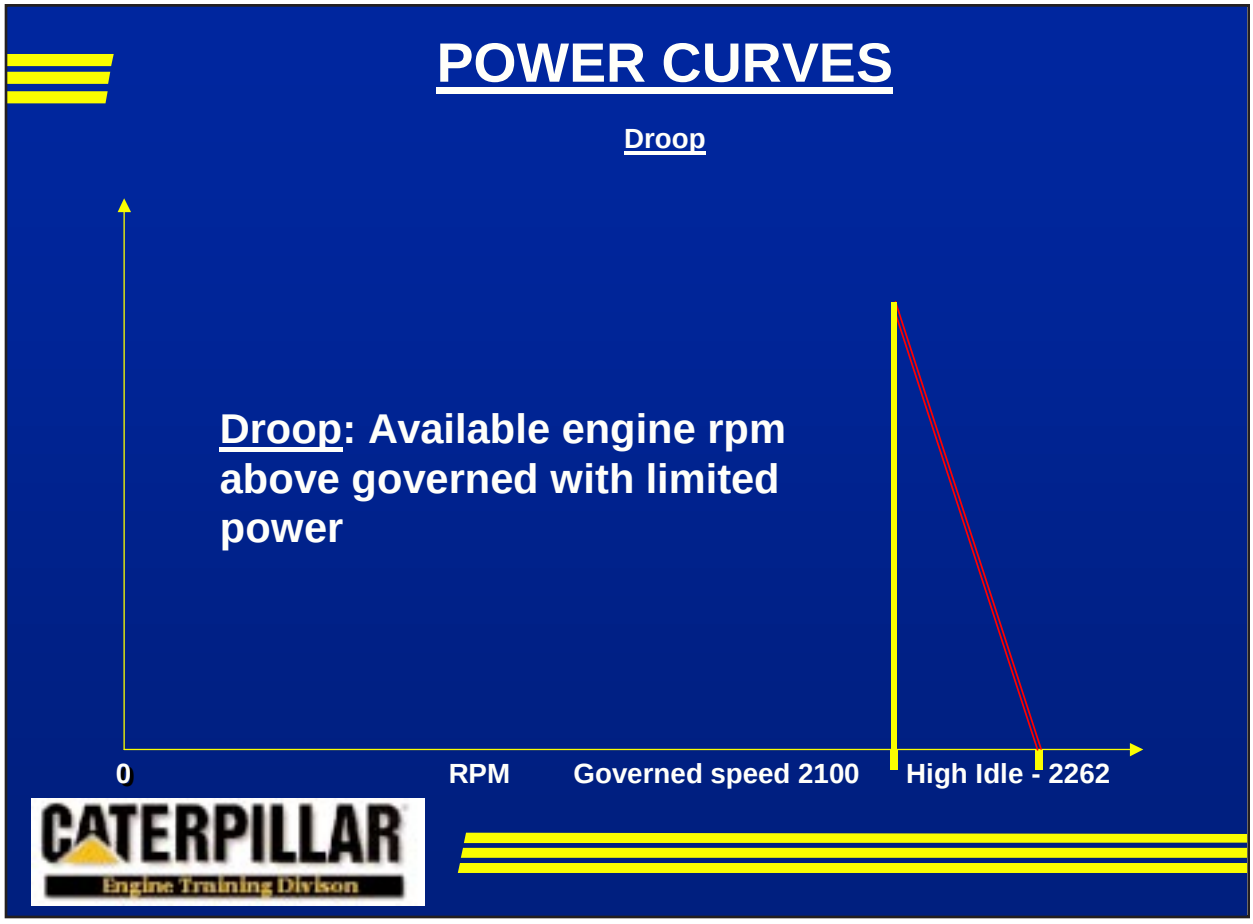


SLIDE 32

High Idle

High idle is the maximum engine speed that can be achieved with no load on the engine as it is installed. This will vary with different paracitic loads. The high idle shown on the engine data tag is a bare engine high idle before any extra devices such as alternators, power steering pumps etc. have been installed. Normal tolerances for a heavy duty high idle is +40/-80 rpm.

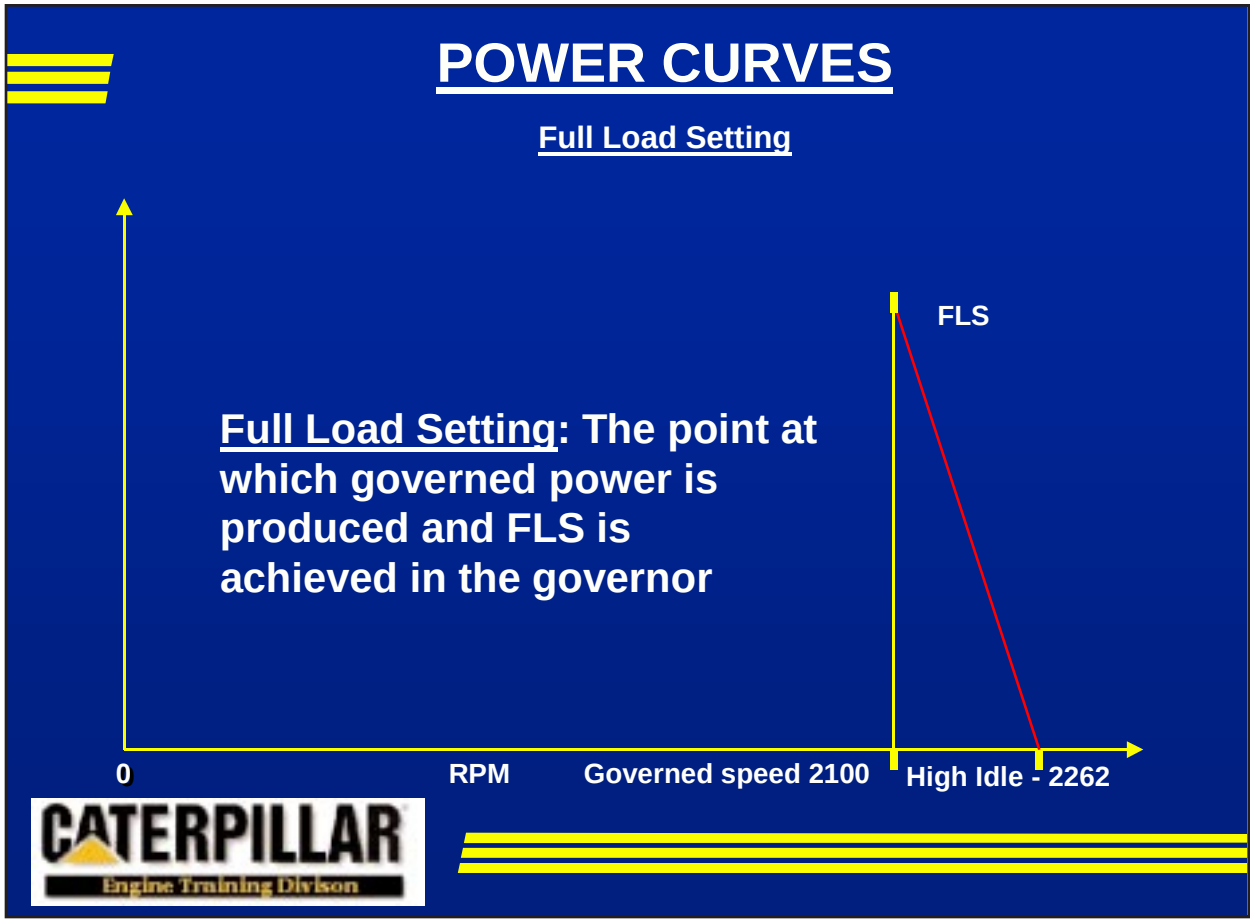
The high idle screw is a stop for maximum deflection of the governor spring which when multiplied by spring rate would give a governor spring force.



SLIDE 33

Droop

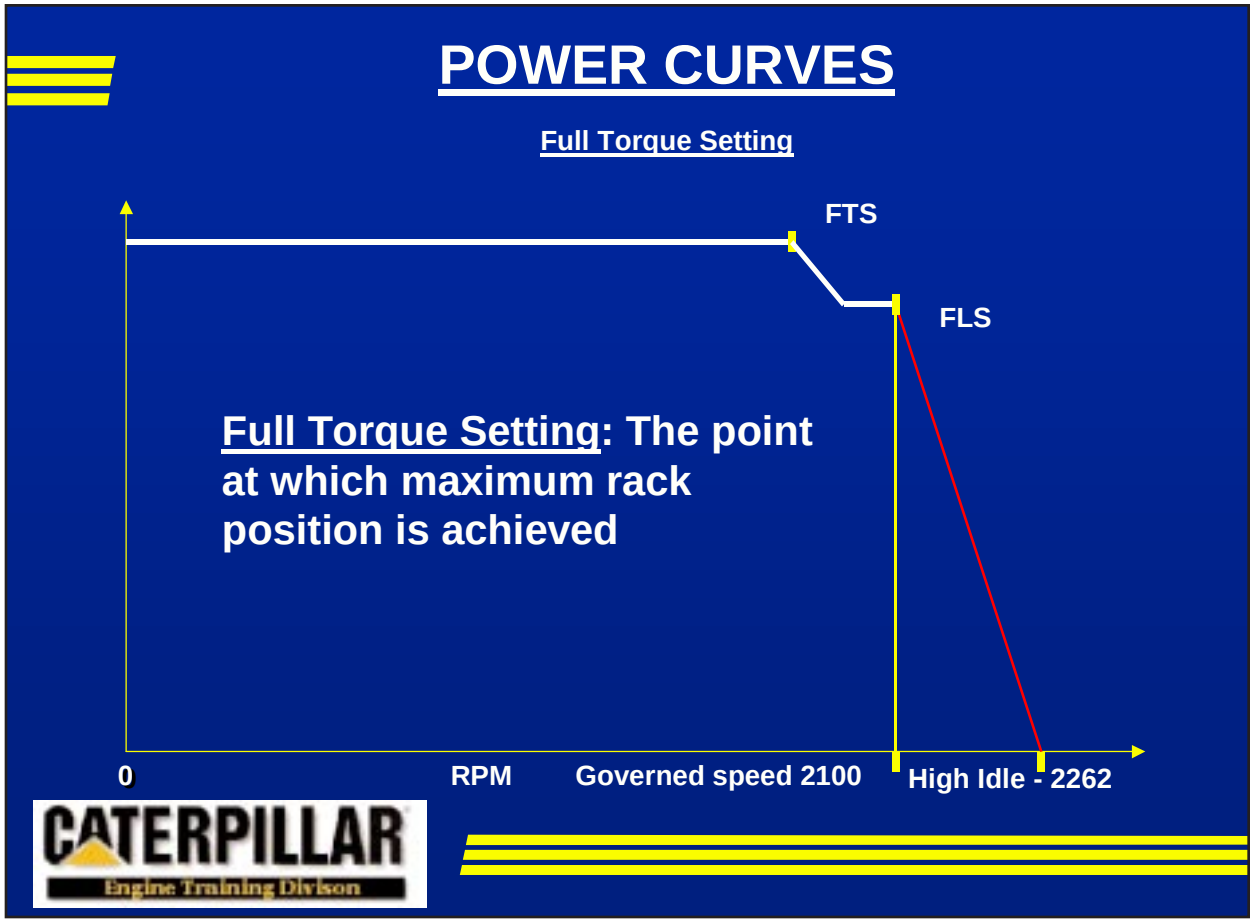
Droop is the engine rpm above governer that is available with limited power. The reason for this is for a smoother transition from full load to no load. With different applications, different droop percents work well. Truck operations prefer 7-10%, power generation requires 0-3% and other applications generally have 5-7%.



SLIDE 34

FLS

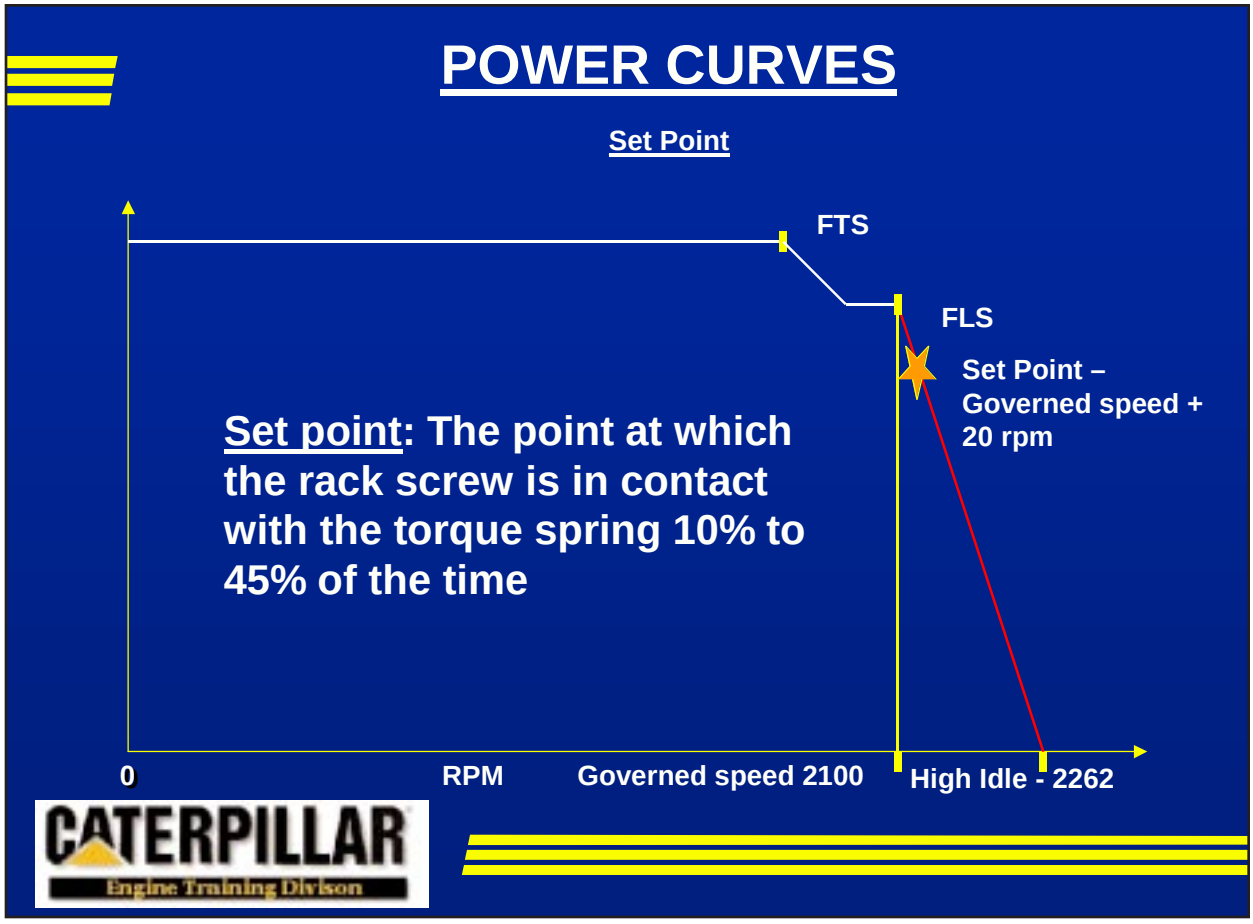
Full load setting is the fuel rack position required to provide advertised governed power for an engine rating. This setting is displayed on the engine data plate. This is the point at which the full load screw is first in full contact with the stop or torque spring if equipped.



SLIDE 35

FTS

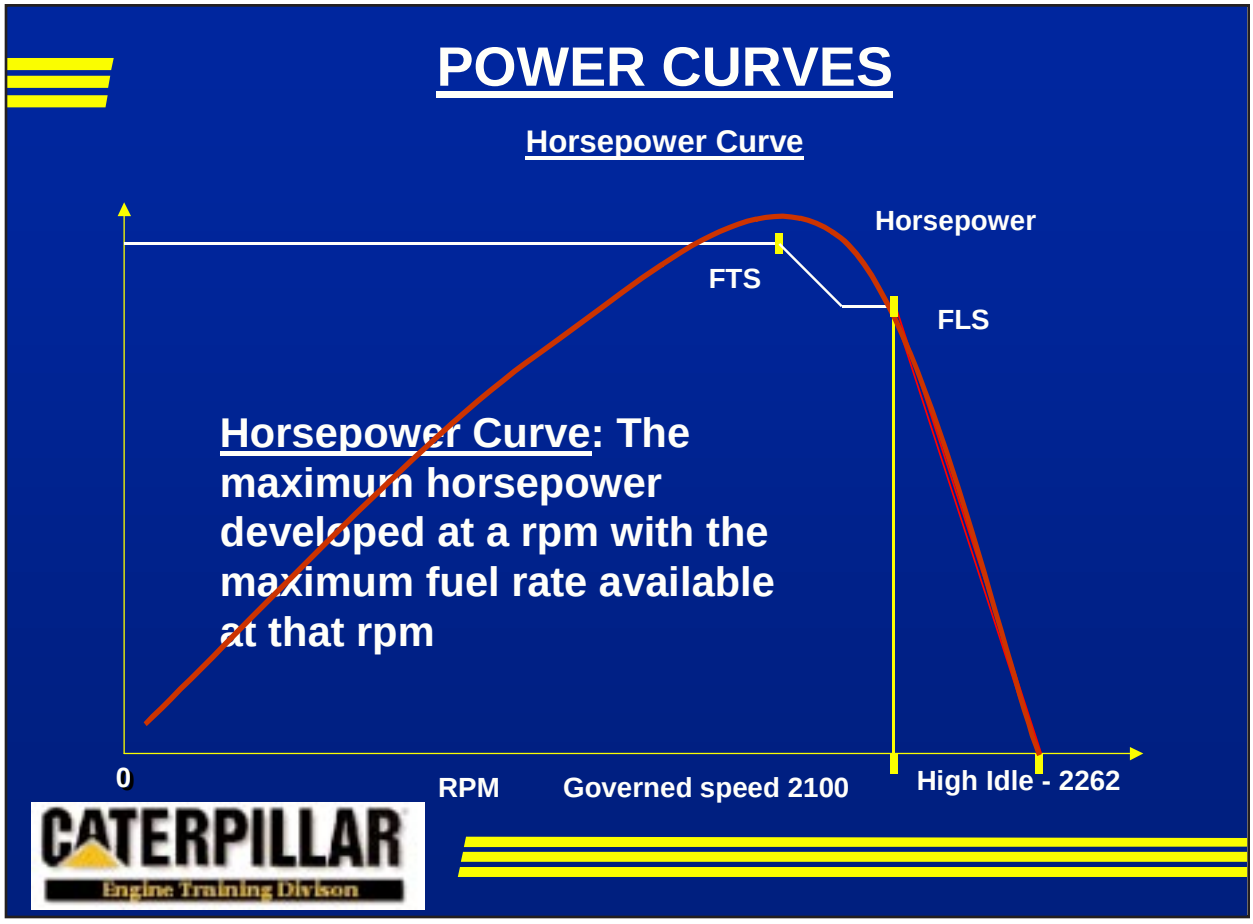
As the engine is lugged below governed speed, flyweight force lowers with a constant governer spring force. This delta P of governor spring force would cause the rack position to increase. Before movement can happen, the force must first be great enough to bend the torque spring. When the force is greater than the torque spring, the rack position increases until the torque screw comes in contact with the solid stop. This rack position is Full Torque Setting (FTS).


POWER CURVES
Set Point
FTS
FLS
Set Point – Governed speed + 20 rpm
Set point: The point at which the rack screw is in contact with the torque spring 10% to 45% of the time
0
RPM
Governed speed 2100
High Idle - 2262
CATERPILLAR
Engine Training Division

SLIDE 36

Set Point

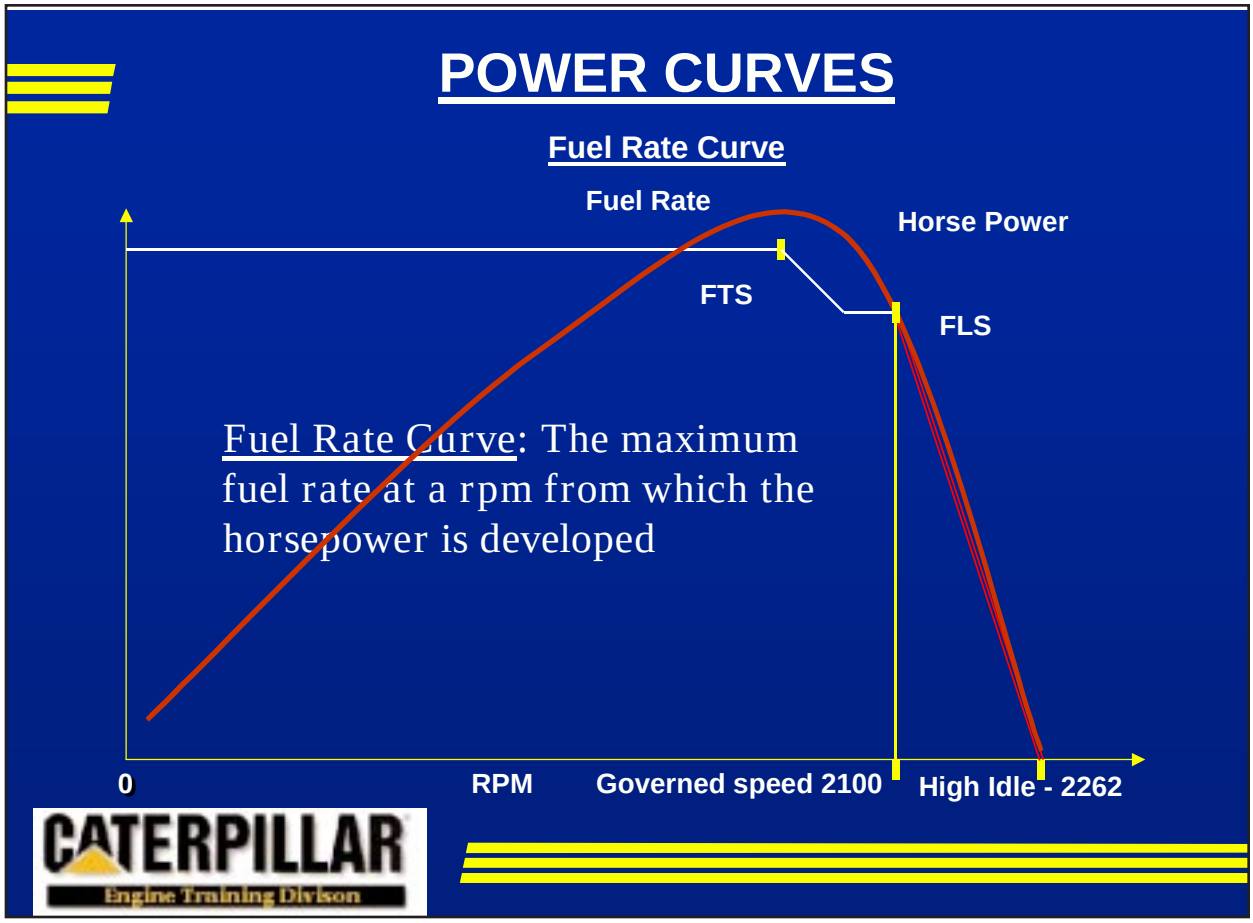
Set Point is the rpm at which the full load screw is in contact with the torque spring between 10 and 45 percent. If we then load the engine down 20 more rpm below set point the full load screw will be first in contact with the torque spring 100 percent which is FLS setting/governed. Therefore governed is always 20 rpm below where we find set point. We set governed by use of set point since we can not exactly determine the first point of 100 percent contact.



SLIDE 37

Horsepower curve

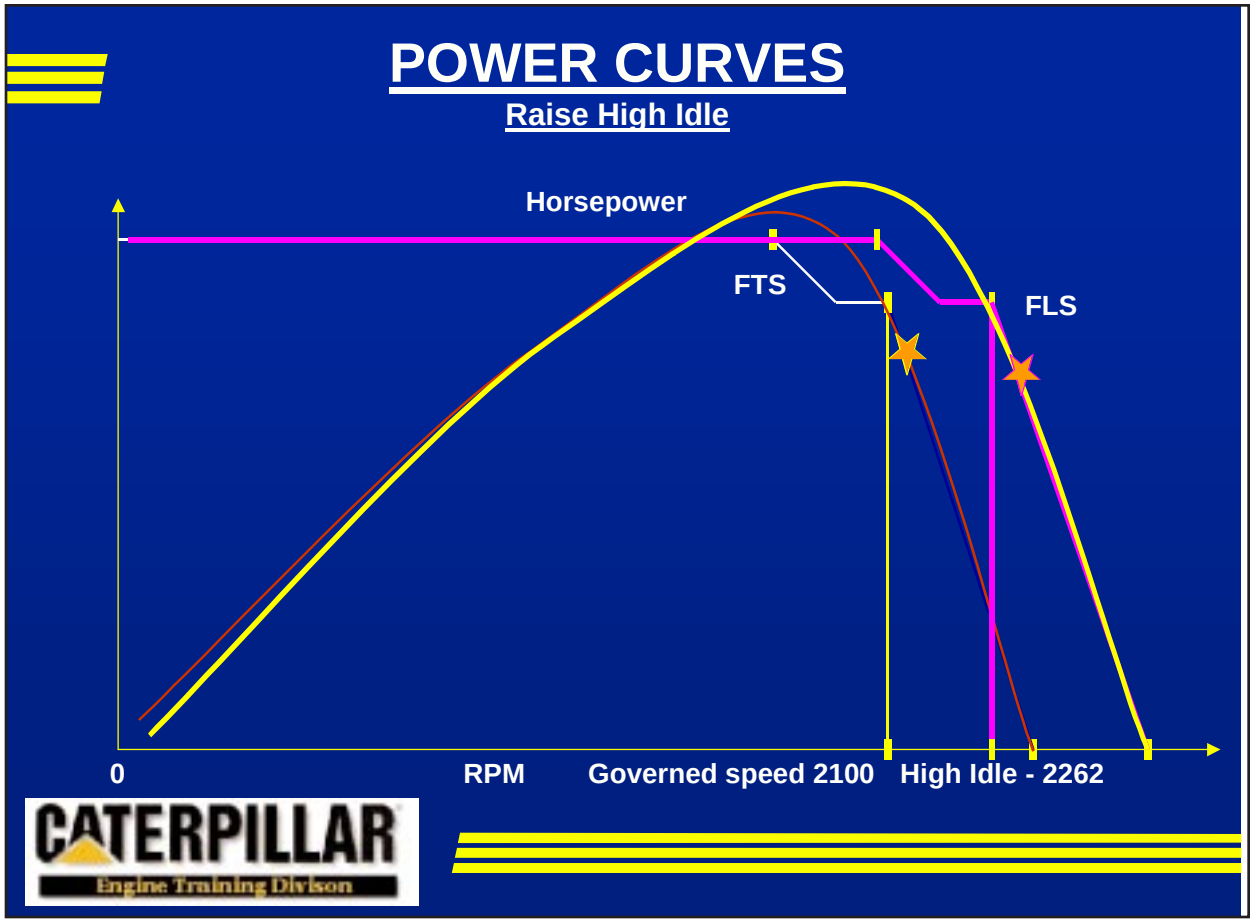
This is the normal shape of a horsepower curve. Typically the horsepower humps up a bit as the rpm lug below governed (stronger torque spring with larger FTS typically). With some curves the power remains flat for a period and then falls off (light torque spring with smaller FTS typically). With some curves the power falls off immediately when the engine goes below governed (no torque spring). With each of these curve shapes, something within the governor is different.



SLIDE 38

Fuel rate curve

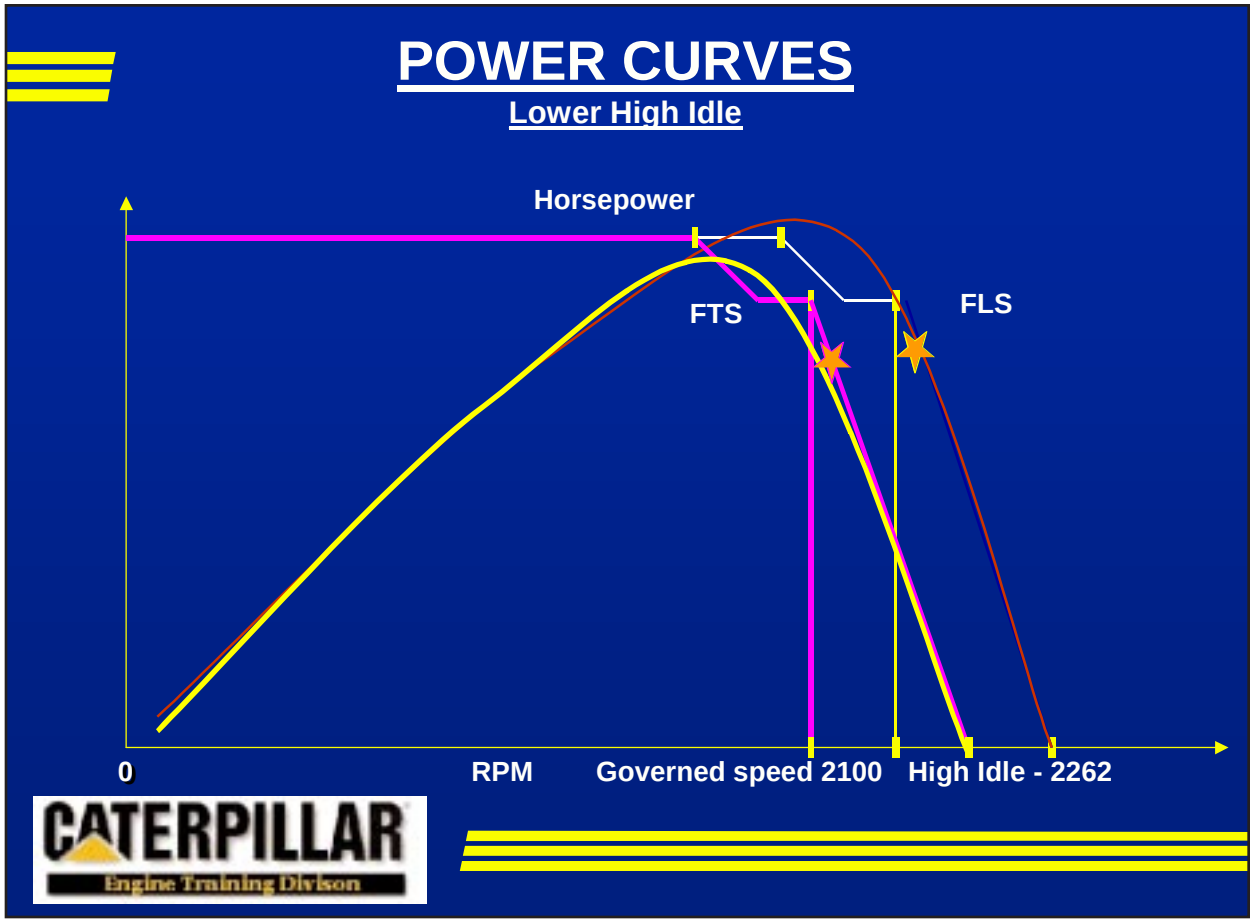
Here we see a typical fuel rate curve. It has a similar shape to the horsepower curve because the horsepower curve comes from the fuel rate curve. We get peak horsepower at the point that FTS is achieved. This is the largest injection volume and the most injections at this volume per hour. As the engine lugs below FTS point, we keep the same injection volume, but inject fewer times per hour. Therefore, fuel rate goes down and due to that, horsepower goes down.



SLIDE 39

When high idle is raised, the rpm at which we achieve FLS goes up. Since FLS rpm is higher, set point is higher. The reason for this is spring rate does not change, so the intersection point of FLS and the droop curve is at a higher rpm.

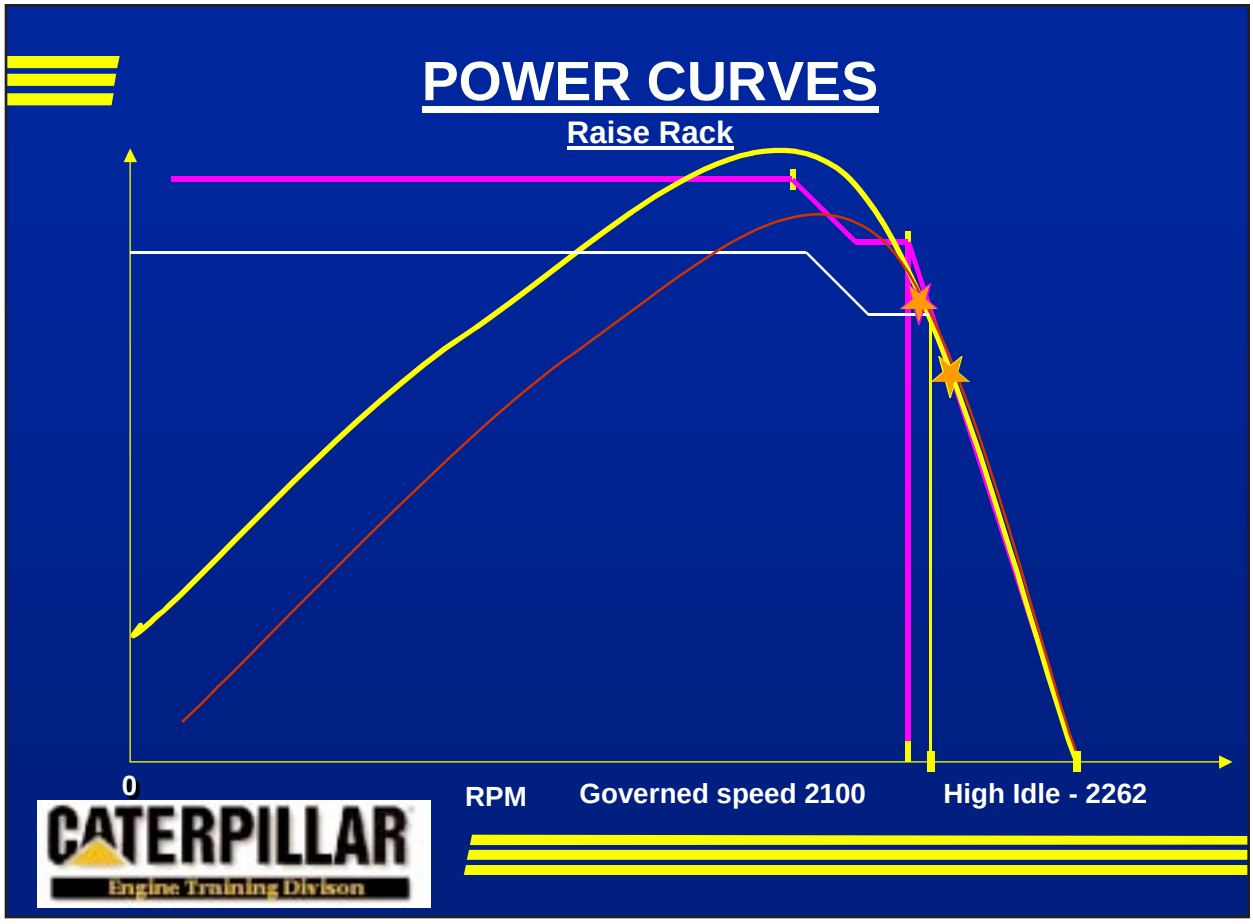
Since we get FLS at a higher rpm, fuel rate at the new governed speed is higher because we get the same injection volume more times per hour. The same is true of FTS setting and fuel rate. The new fuel rate and horsepower curves are as shown with the yellow curve.



SLIDE 40

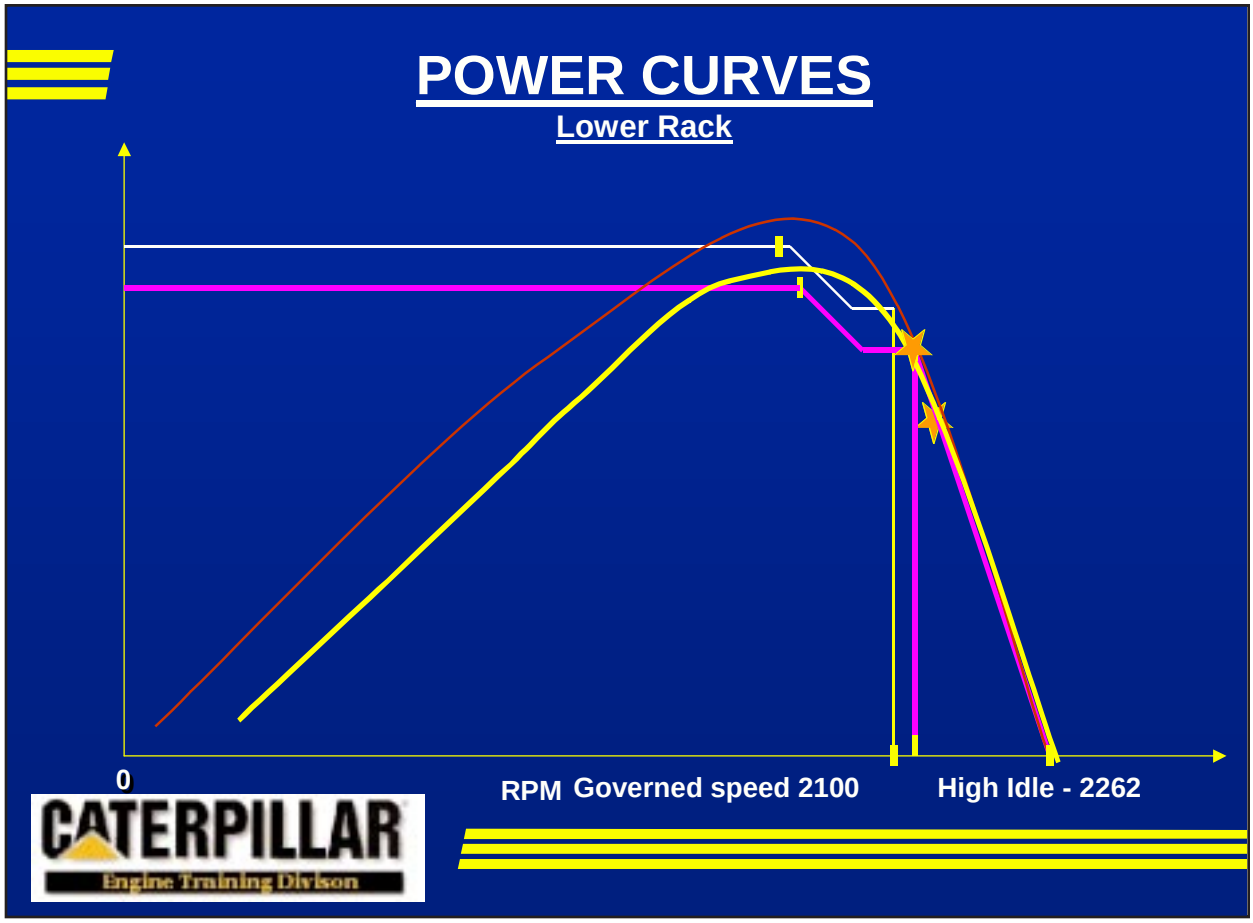
When high idle is lowered, the rpm at which we achieve FLS goes down. Since FLS rpm is lower, set point is lower. The reason for this is spring rate does not change, so the intersection point of FLS and the droop curve is at a lower rpm.

Since we get FLS at a lower rpm, fuel rate at the new governed speed is lower because we get the same injection volume less times per hour. The same is true of FTS setting and fuel rate. The new fuel rate and horsepower curves are as shown with the yellow curve.



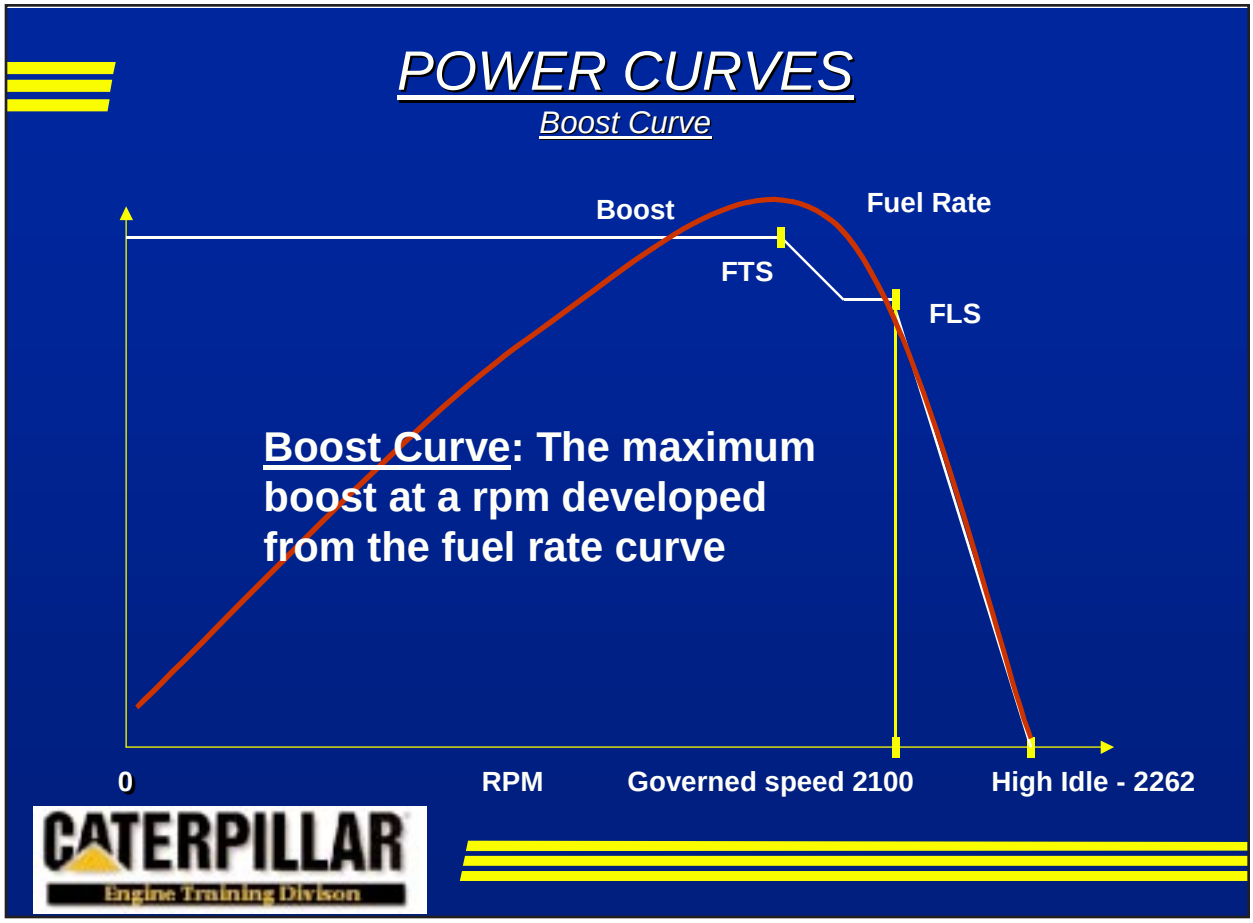
SLIDE 41

As FLS is raised, the engine must be at a lower rpm to find the intersection of the droop curve and FLS. This would lower the rated rpm, therefore lowering set point rpm.



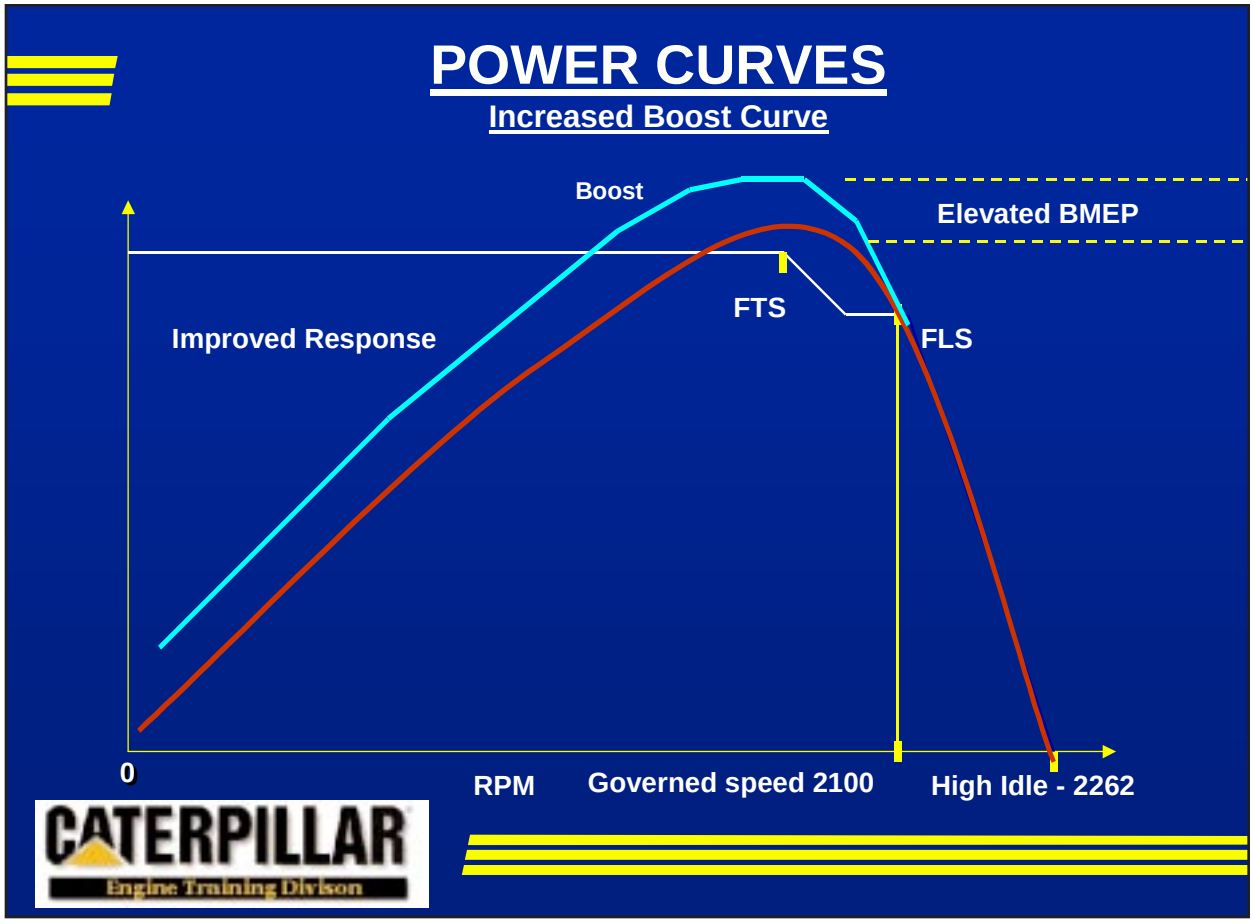
SLIDE 42

As FLS is lowed, the engine must be at a higher rpm to find the intersection of the droop curve and FLS. This would raise the rated rpm, therefore raising set point rpm.



SLIDE 43

Boost is a product of fuel rate. The amount of fuel injected along with the availability of air produces exhaust gases which drive the turbocharger turbine. The speed of the turbine determines the boost coming from the turbocharger. This boost can then be diminished by leaks and restrictions.

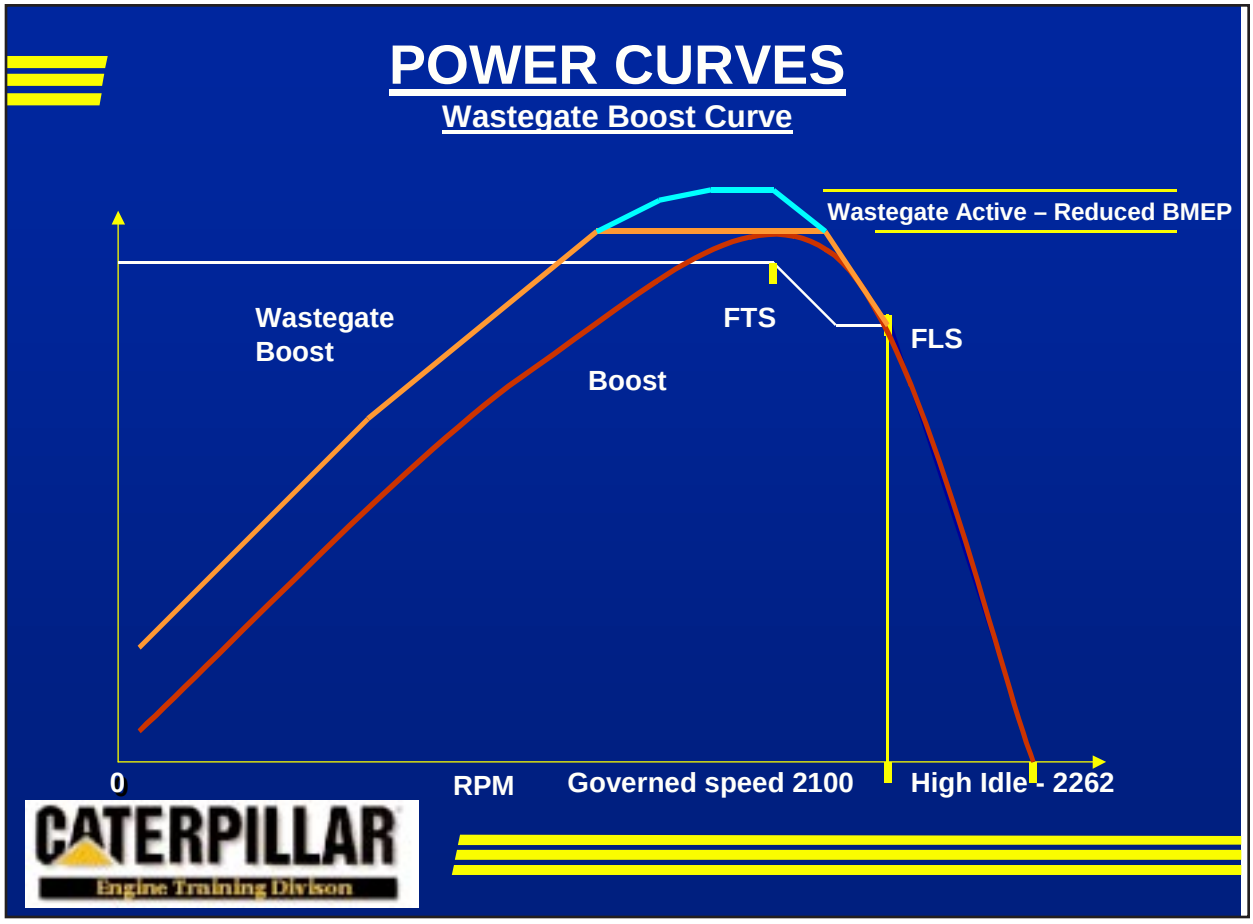


SLIDE 44

Boost is directly proportional to responsiveness of the engine. For efficiency, the engine operating rpm is normally a few rpm above peak torque. At this lower rpm, boost is lower since fuel rate is lower.

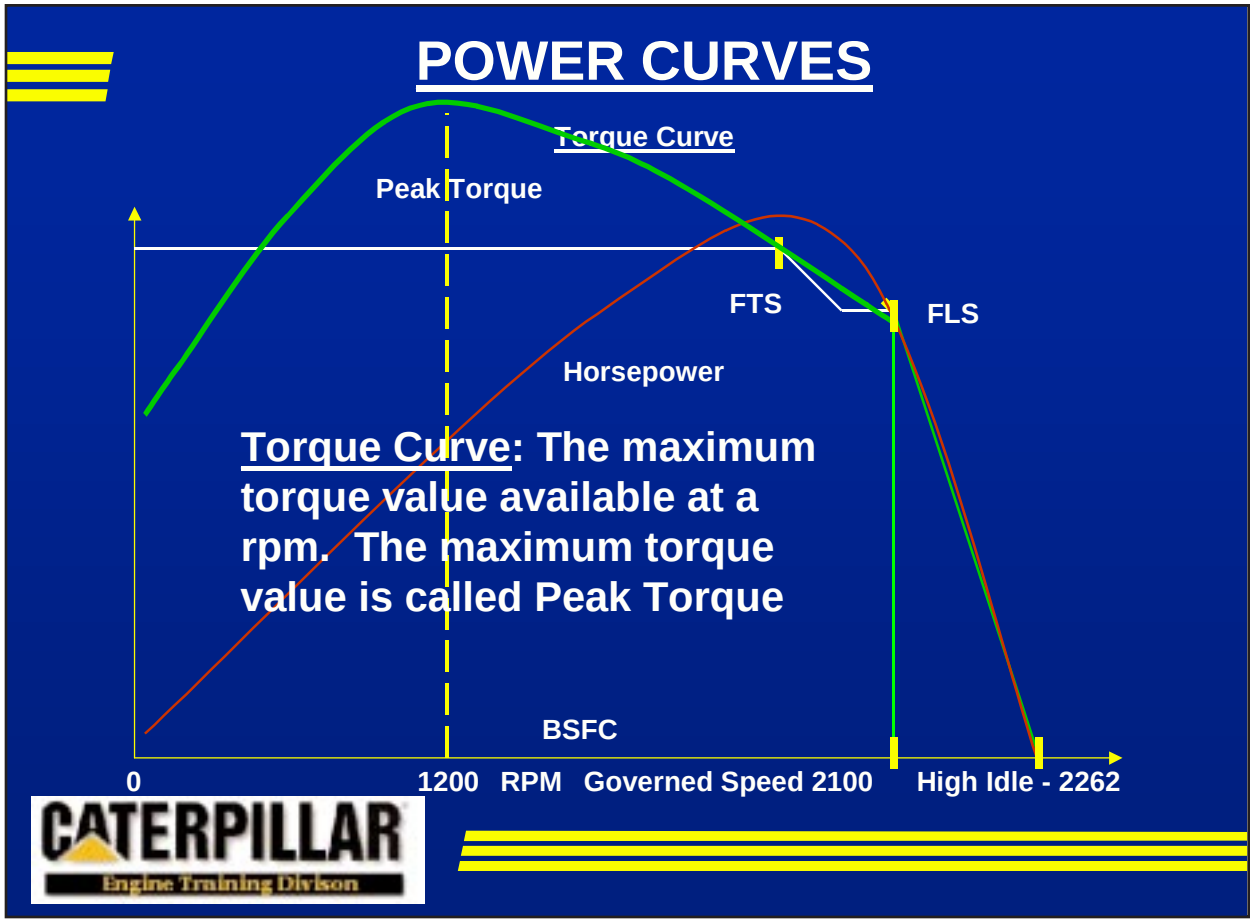
The engine, although efficient, is somewhat less responsive. To combat this natural loss of response, a wastegate turbocharger may be installed. With the wastegate closed, boost is elevated with the same fuel rate. This improves the responsiveness of the engine at lower rpm.

As boost is elevated, BMEP Brake Mean Effective Pressure (Average cylinder pressure) goes up. If this pressure is allowed to get above engine limits, premature engine failure can occur.



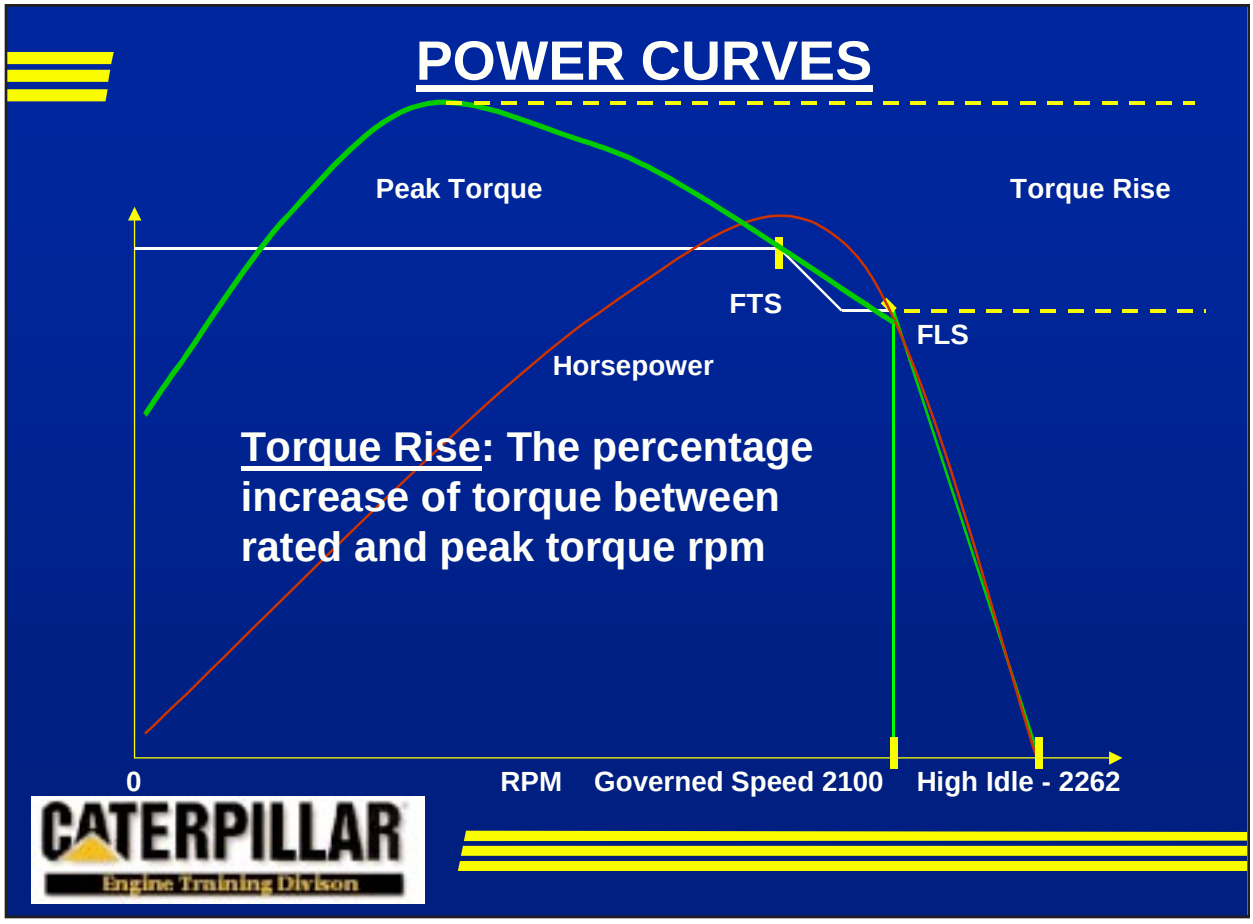
SLIDE 45

To reduce possible failure rates, we use a wastegate valve to funnel some of the exhaust gases around the turbine to limit maximum boost and therefore limit BMEP. Plugging or clamping off the wastegate line by the customer would cause revocation of warranty since the engine could operate in a higher than desired BMEP range.



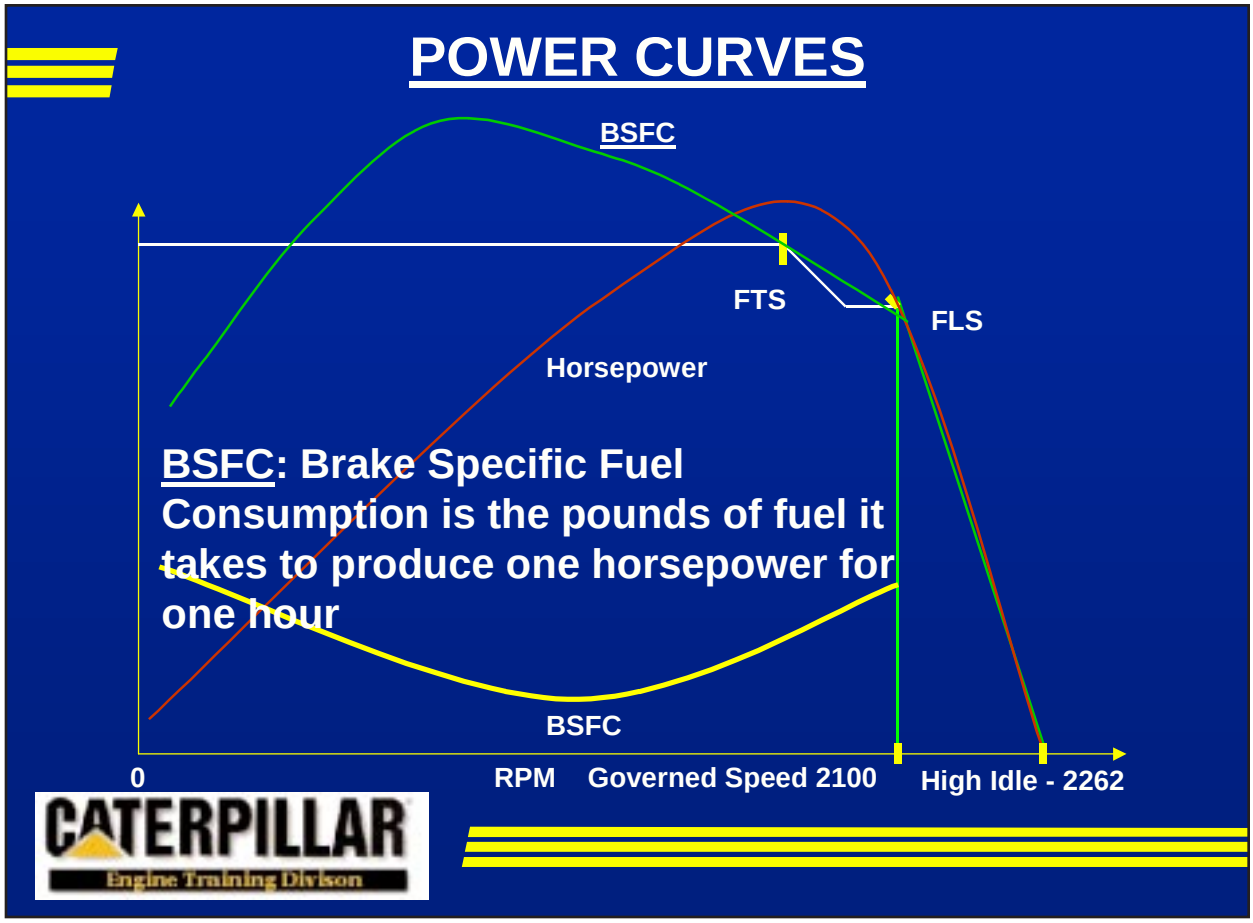
SLIDE 46

The torque curve is the one that the customer really uses. It is the pound feet of twisting force that propels whatever is being turned. The torque curve does not follow the fuel rate curve. Instead it continues to rise with lower rpm and fuel rate. This is caused by slower pistons speeds giving the fuel more time to burn and reduced internal paracitic loads within the engine.



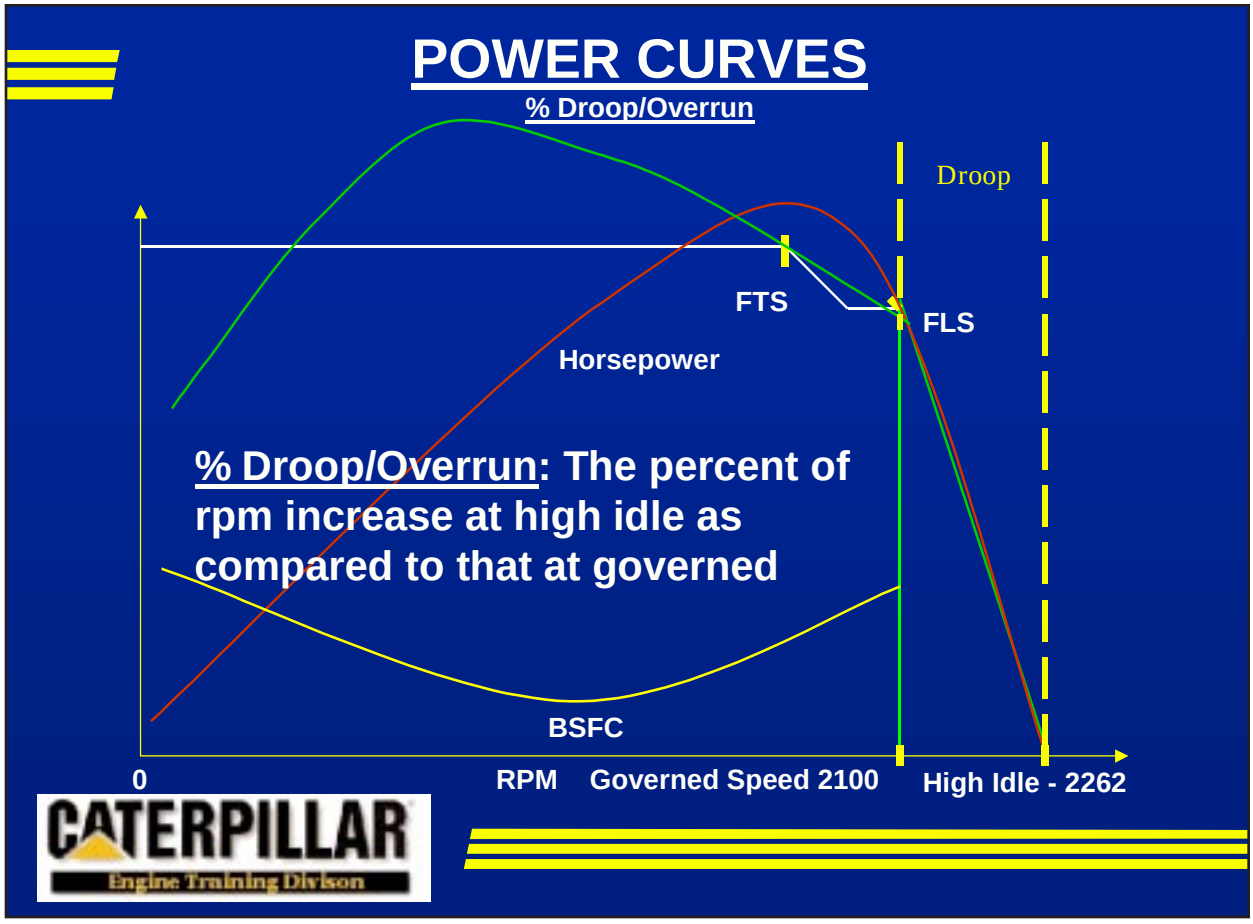
SLIDE 47

Torque rise is the percentage difference between the torque available at rated versis the torque available at peak torque rpm. The torque of the engine is its true power. At peak torque rpm we find the most torque with a lowered fuel volume. Therefore the operator gets more force for less fuel when the engine is operated at a lower rpm.



SLIDE 48

The efficiency of the engine is recorded by the use of BSFC (Brake Specific Fuel Consumption). This is the amount of fuel in pound per horsepower hour or grams per kilowatt hour. The smaller the number, the more efficient the engine. The engines are designed to provide the best fuel efficiency at the recommended operating rpm. This number changes with both rpm and power demand. The curve shown is a full load BSFC curve.



SLIDE 49

Droop or overrun is the percent of rpm the engine is allowed to run above governed and compared to governed rpm. This droop area allows the power to taper off at a rate that is compatable with the type of engine operation.

No droop is desirable for Generators. They need the same rpm regardless of power demand. Some engine governors have slight droop that can not be adjusted out. 0-3% droop is normal for this application.

Marine, Industrial and machines normally have 5-7% droop while trucks have 7-10% droop.

Small Engine Fuel Systems

Lesson Plan 6 - Performance Correction Factors

Objectives:

- The student will be able to calculate expected horsepower loss or gain due to fuel API with at least 70% accuracy on a written test.
- The student will be able to explain operation of a fuel sight glass with at least 70% accuracy on a written test.

Literature Needed:

Test Condition Slide Script	Copy
Engine Performance Reference	LEXT1044
Fuel and Your Engine	SEBD0717

Hardware Needed:

Slide Projector

Screen

Test Conditions Slide

Chalk and Chalkboard

Time Required:

1.25 Hours

Tasks Required by Instructor to Meet Objectives:

1. Review Standard Caterpillar Test Conditions
   A. Fuel API - 35° API @ 60° F
   B. Fuel Temperature - 85° F at the outlet of the fuel filter base
   C. Air Temperature
      1. JWAC, T and NA - 77° F after the air filter and before the turbocharger if it has one.
      2. ATAAC - 110° F in the intake manifold
   D. Barometric Pressure - 29.61 or 30.5 if relative humidity and air cleaner are

accounted for

2. Review the affects the above operating conditions have on engine performance.
3. Discuss how correction factors are determined and multiplied to obtain a "Total Correction Factor"
4. Give students several sets of operating conditions and have them calculate the Total Correction Factors and apply them to a given engine rating.
   A. Example: What is the expected flywheel horsepower of a 3126E rated at 300 @ 2200 if the fuel is 39° API @ 40°F, fuel temperature is 140°F, air intake temperature is 90°F, and barometric pressure is 30.15?

      40.6° API @ 60° F

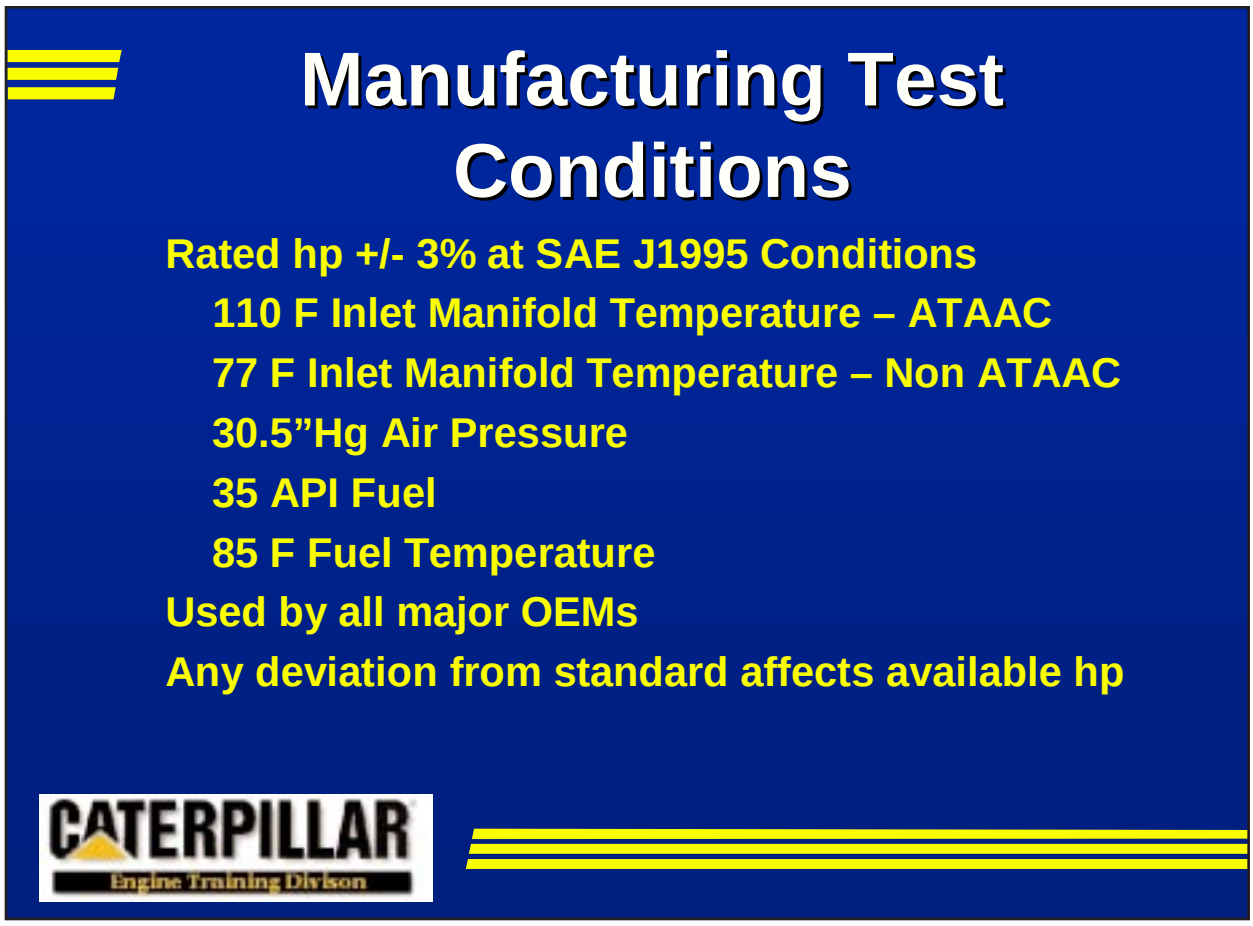
      300 ÷ (1.025 X 1.055 X 0.987 X 1.002) = 280.5

   B. Example: What is the expect flywheel horse power of a 3116 rated at 215 @ 2600 if the fuel is 41° API @ 40°F, fuel temperature is 120°F, air intake temperature is 95°F, and barometric pressure is 30.45?

      42.7° API @ 60° F

      215 ÷ (1.034 X 1.035 X 0.990 X 1.000) = 203
5. Discuss the importance of analyzing each operating condition and the effect it has on horsepower

2. Ask if there are any questions and explain the answers using the reference material.


Manufacturing Test Conditions
Rated hp +/- 3% at SAE J1995 Conditions
110 F Inlet Manifold Temperature – ATAAC
77 F Inlet Manifold Temperature – Non ATAAC
30.5”Hg Air Pressure
35 API Fuel
85 F Fuel Temperature
Used by all major OEMs
Any deviation from standard affects available hp
CATERPILLAR
Engine Training Division

SLIDE 50

All Caterpillar engines are tested to SAE J1995 conditions. A tolerance of +/- 3 % is held. This tolerance is held when all operating conditions are standard:

110 degree F Inlet Manifold Temperature - ATAAC

77 degree F Inlet Manifold Temperature - Non ATAAC

30.5” Hg Barometric Pressure (29.62” Hg in factory test conditions)

35 API Fuel

85 degree F Fuel Temperature

This form of testing is used by all of the OEMs with slightly different operating conditions.

Any deviation from the standard condition affects the engine’s available horsepower

Small Engine Fuel Systems

Lesson Plan 7 - Quiz 1

Objectives:

- The student will take a quiz to review and test the previous day's material. A minimum of 70% accuracy is considered acceptable.

Literature Needed:

Quiz 1 Copy

Hardware Needed:

None

Time Required:

0.5 Hour

Tasks Required by Instructor to Meet Objectives:

1. Ask students for questions regarding material covered the previous day.
2. Answer all questions using reference material. Be sure the students follow along in their reference material while the question is answered.
3. Administer the Quiz 1.
4. Review the Quiz 1, again using reference material to answer questions.

Small Engine Fuel Systems

Lesson Plan 7 - Quiz 1

Select the best answer - If the answer is false on a true/false, correct the question to make it true.

1. The largest single operating expense over the life of an engine is
   A. Purchase price.
   B. Repairs.
   C. Preventive maintenance.
   D. Fuel.

2. Specific gravity (API) of fuel is measured with a
   A. Hygrometer
   B. Thermometer
   C. Hydrometer
   D. Pyrometer
   E. Viscometer

3. The standard fuel API for CAT diesel engines is.
   A. 35° API @ 50° F
   B. 41° API @ 60° F
   C. 38° API @ 50° F
   D. 35° API @ 60° F

4. One gallon of diesel fuel, 39 API° @ 60°F, weighs

   A. 7.206 lbs.

   B. 7.000 lbs.

   C. 7.076 lbs.

   D. 6.910 lbs.

5. Engine fuel settings should be adjusted to compensate for power loss with lighter fuels.

   A. True

   B. False

6. Cetane number indicates the BTU content of a fuel.

   A. True

   B. False

7. The pour point of a fuel indicates the temperature at which wax crystals begin to form.

   A. True

   B. False

8. High sulfur content in diesel fuel can result in

   A. Excessive liner wear.

   B. High power output.

   C. High oil consumption.

   D. Excessive blowby.

   E. B, C and D

   F. A, C and D

   G. All of the above.

9. What is the corrected API of a fuel that has a measured value of 43° API at 30° F?

10. Always pour clean fuel into a new fuel filter element before you install it.

    A. True

    B. False

Small Engine Fuel Systems

Lesson Plan 7 - Quiz 1

Select the best answer - If the answer is false on a true/false, correct the question to make it true.

1. The largest single operating expense over the life of an engine is: D
   A. Purchase price.
   B. Repairs.
   C. Preventive maintenance.
   D. Fuel.

2. Specific gravity (API) of fuel is measured with a C
   A. Hygrometer
   B. Thermometer
   C. Hydrometer
   D. Pyrometer
   E. Viscometer

3. The standard fuel API for CAT diesel engines is. D
   A. 35° API @ 50° F
   B. 41° API @ 60° F
   C. 38° API @ 50° F
   D. 35° API @ 60° F

4. One gallon of diesel fuel, API 39° @ 60°F, weighs D

   A. 7.206 lbs.

   B. 7.000 lbs.

   C. 7.076 lbs.

   D. 6.910 lbs.

5. Engine fuel settings should be adjusted to compensate for power loss with lighter fuels. B - should not

   A. True

   B. False

6. Cetane number indicates the BTU content of a fuel. B - Ignition quality

   A. True

   B. False

7. The pour point of a fuel indicates the temperature at which wax crystals begin to form. B - Cloud Point

   A. True

   B. False

8. High sulfur content in diesel fuel can result in F

   A. Excessive liner wear.

   B. High power output.

   C. High oil consumption.

   D. Excessive blowby.

   E. B, C and D

   F. A, C and D

   G. All of the above.

9. What is the corrected API of a fuel that has a measured value of 43° API at 30° F?

   45.6° API @ 60°F

10. Always pour clean fuel into a new fuel filter element before you install it.

    B - Never

    A. True

    B. False

Small Engine Fuel Systems

Lesson Plan 8 - Fuel Setting Information

Objectives:

- The student will be able to select proper 0T/2T/0K and Performance Information from the TMI on-line system in a lab exercise and with at least 70% accuracy on a written test.
- The student will be able to select appropriate engines for a task by looking at various performance sheets in a classroom lab exercise.

Literature Needed:

Sample 0T/2T from TMI/SIS or SIS Web	Copy
Sample Engine Performance Information from TMI	Copy

Hardware Needed:

On-line Terminal

Time Required:

1 Hour

Tasks Required by Instructor to Meet Objectives:

1. Explain the method of retrieving 0T/2T/0K information, using the TMI on line system and/or SIS system.
2. Find and print a copy of the 0T/2T/0K information and engine performance information for a 3116 engine with a 250 @ 2600 rating using the TMI on-line system.
3. Review the type and placement of all of the data on the above two documents. Discuss any tolerances that may apply to the engine performance information.
4. Answer any questions about the 0T/2T/0K and/or the performance information.

Small Engine Fuel Systems

Lesson Plan 9 - Introduction to 1.1 and 1.2 MUI Fuel Systems

Objectives:

- The student will be able to explain the operation, disassembly, assembly, setting procedure and testing of the 1.1 and 1.2 liter MUI fuel system with 70% accuracy on a written test.

Literature Needed:

1.1 Liter Fuel System Slide Script	Copy
Systems Operation T & A, 3114, 3116, 3126 Engines	SENR3583
Torque Specifications	SENR3130

Hardware Needed:

Slide Projector

Screen

1.1 Liter Fuel System Slides

Time Required:

1.25 Hours

Tasks Required by Instructor to Meet Objectives:

1. Review the slides and emphasize the following points:
   A. Fuel flow throughout the engine
   B. Transfer pump and system check valves
   C. Types and operation of shutoff solenoids
   D. Unit injector operation
   E. Types and operation of the governor
   F. Fuel settings and injector adjustments using the 128-8822 Tool Group
2. Using Systems Operation Testing and Adjusting discuss where the following information can be found:
   A. Fuel pressure location

B. Timing hole location

C. Injector synchronization

D. Fuel Setting

E. Fuel timing

3. Using the Tool Operation Manual discuss where the following information can be found:

A. Injector synchronization

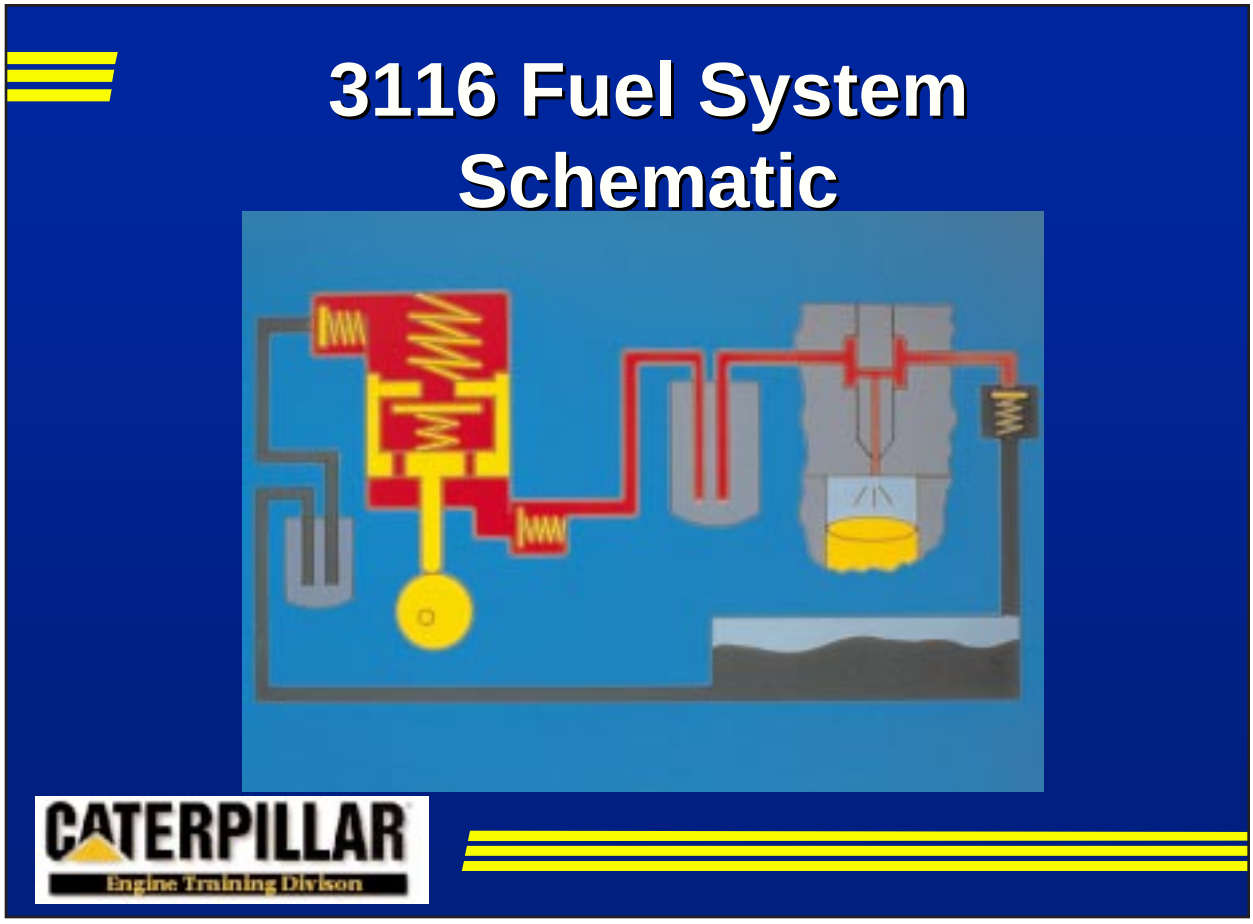
B. Fuel Setting

C. Fuel timing

3. Using the Governor Service Manual discuss where the following information can be found:

A. Governor disassembly and assembly procedures

B. Governor testing and adjusting procedures



SLIDE 51

Fuel flow

Fuel tank

Primary filter

Fuel transfer pump

Check valves

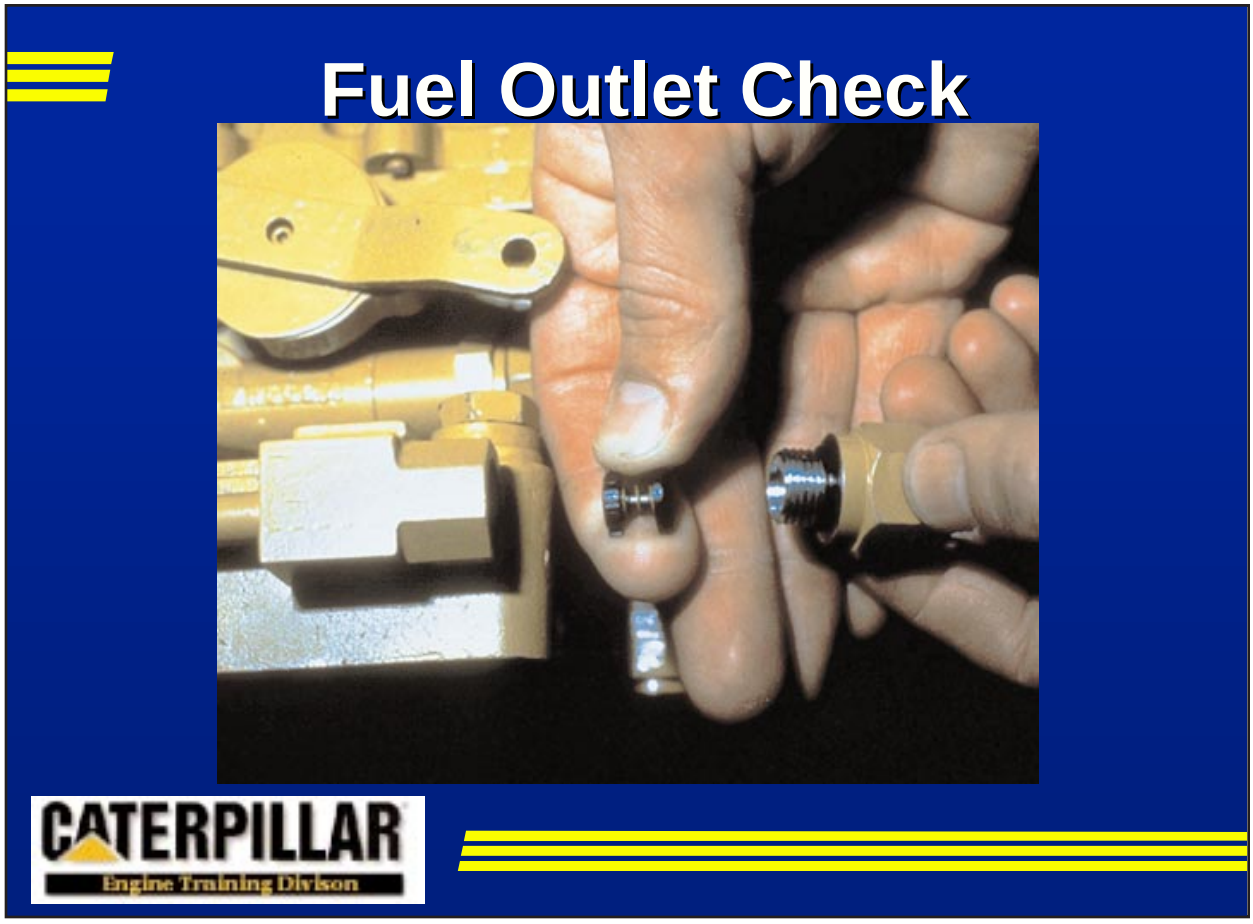
Secondary filter

Cylinder head

Unit injectors

Orifice

The 1.1 liter engine fuel system employs a mechanical unit injector combining both the nozzle assembly and the high pressure fuel injection pump. The fuel transfer pump (1) pulls fuel from the fuel tank through an in-line primary filter (2) and sends fuel to a spin-on type secondary fuel filter (3). From the fuel filter, fuel enters a drilled passage at the rear of the cylinder head. The drilled passage carries fuel to a gallery around each unit injector and provides a continuous flow of fuel to all of the unit injectors. Unused fuel exits the cylinder head, passes through a 1.3 mm (.050 in) pressure regulating orifice and a check valve (4) and returns to the fuel tank (5). This system is very compact; eliminates external high pressure fuel lines. Additionally, this system allows very high injection pressures and short injection times, with subsequent emission control.



SLIDE 52

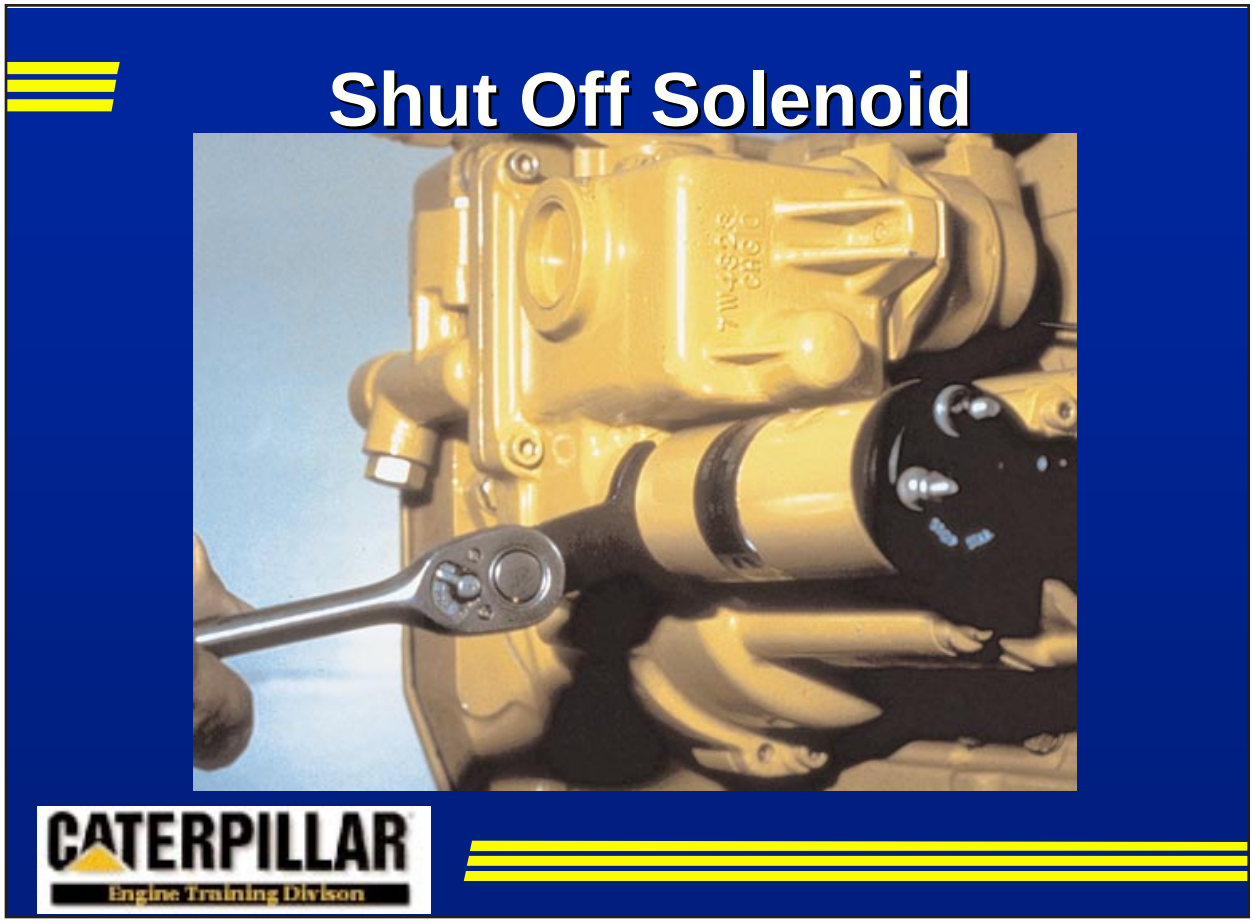
Check valves

Start up

Transfer Pump

The check valve shown keeps fuel from bleeding out of the fuel gallery after shutdown to ensure a fuel supply for start-up. This is the same design valve as is used in the transfer pump. The pressure regulating orifice ensures adequate fuel pressure and controls the return-to-tank flow rate.

The fuel transfer pump is located in the front housing of the governor. It is a piston-type pump actuated by an eccentric on the governor drive shaft and driven by the governor gear.



SLIDE 53

Shutoff solenoids

Latching

12 or 24 volts

A latching solenoid with two coils and a mechanical latch is installed on this governor. The solenoid is energized to latch and then de-energized. It is energized again to release the latch. It also has manual “latch” and “release” functions to provide “limp home” and manual shutoff capabilities.

Solenoids are available for 12 and 24 volt applications. Also, some applications (trucks and gen sets) will use a conventional (non-latching) “energize-to-run” solenoid to allow automatic shutdown systems to shut off the engine by interrupting power to the solenoid.

The spanner wrench (9U5120) shown is necessary for solenoid removal.

SLIDE 54

Unit injectors

Fuel lines

The fuel injection system for this engine is a mechanical unit injector type. The fuel injection pump and nozzle are combined in one injector assembly for each cylinder. All high pressure lines are eliminated. Fuel lines consist of supply lines to and from the cylinder head, fuel filter and fuel transfer pump. Fuel is supplied to each injector by an internal passage running the full length of the head. Each unit injector has its own fuel rack, controlled by the governor with a rack control linkage which actuates all of the unit injectors simultaneously.

SLIDE 55

Hold down clamp

Rack

Plunger

Nozzle

Total stroke

Effective stroke

The large extension on the side of the injector is the hold-down clamp. Shown on the bottom injector is the rack. Its movement controls the rotation of the helix on the scroll of the plunger, thus determining the volume of fuel to be injected into the cylinder. The unit injector consists of a scroll-type high pressure plunger and injector nozzle. Effective stroke of the plunger, during which high pressure fuel is injected, is controlled by the scroll position which is actuated by the governor and rack. This system is basically like other Caterpillar scroll type fuel systems except the high pressure pumps are separated and individually positioned above each combustion chamber thereby eliminating the need of high pressure fuel lines. Total plunger stroke is always the same and determined by the cam lobe lift and rocker arm motion. The effective stroke, however, is determined by the scroll position. The plunger rotates about its vertical axis to move the scroll, hence, lengthening or reducing the effective stroke. During the time both ports are covered, fuel is injected. Fuel pressure forces the check

off its seat for injection, and once pressure drops, a spring closes the check. Fuel surrounds the injector from the top o-ring to the raised sealing ring at the base of the nozzle cone.

SLIDE 56

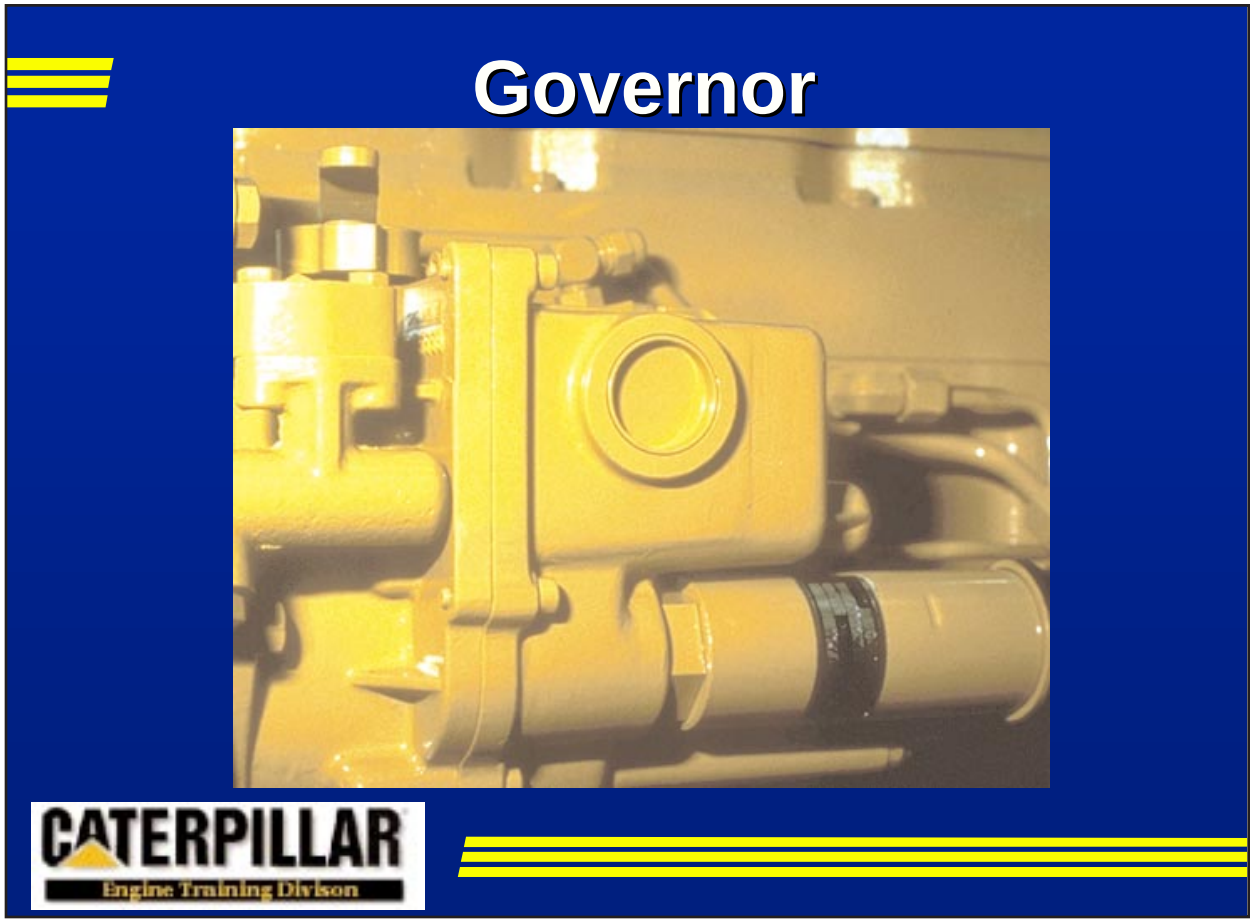
Remove the unit injector

Drain fuel

Hold down bolt

Do not pry on clamp

To remove the unit injector, first drain the fuel from the cylinder head, to prevent fuel from entering the cylinder when the injector is removed. This is particularly important if a catalytic converter is installed since raw fuel can cause damage to them. Remove the injector hold-down bolt. Then, being careful not to damage the injector rack, insert the pry bar in the notch at the base of the injector and loosen the injector in the bore. Do not pry on the injector hold down clamp since this would distort it. Rotate the injector clockwise to assure that the rack head clears the rack shaft before removing the injector.



SLIDE 57

Governor

Flyweight type

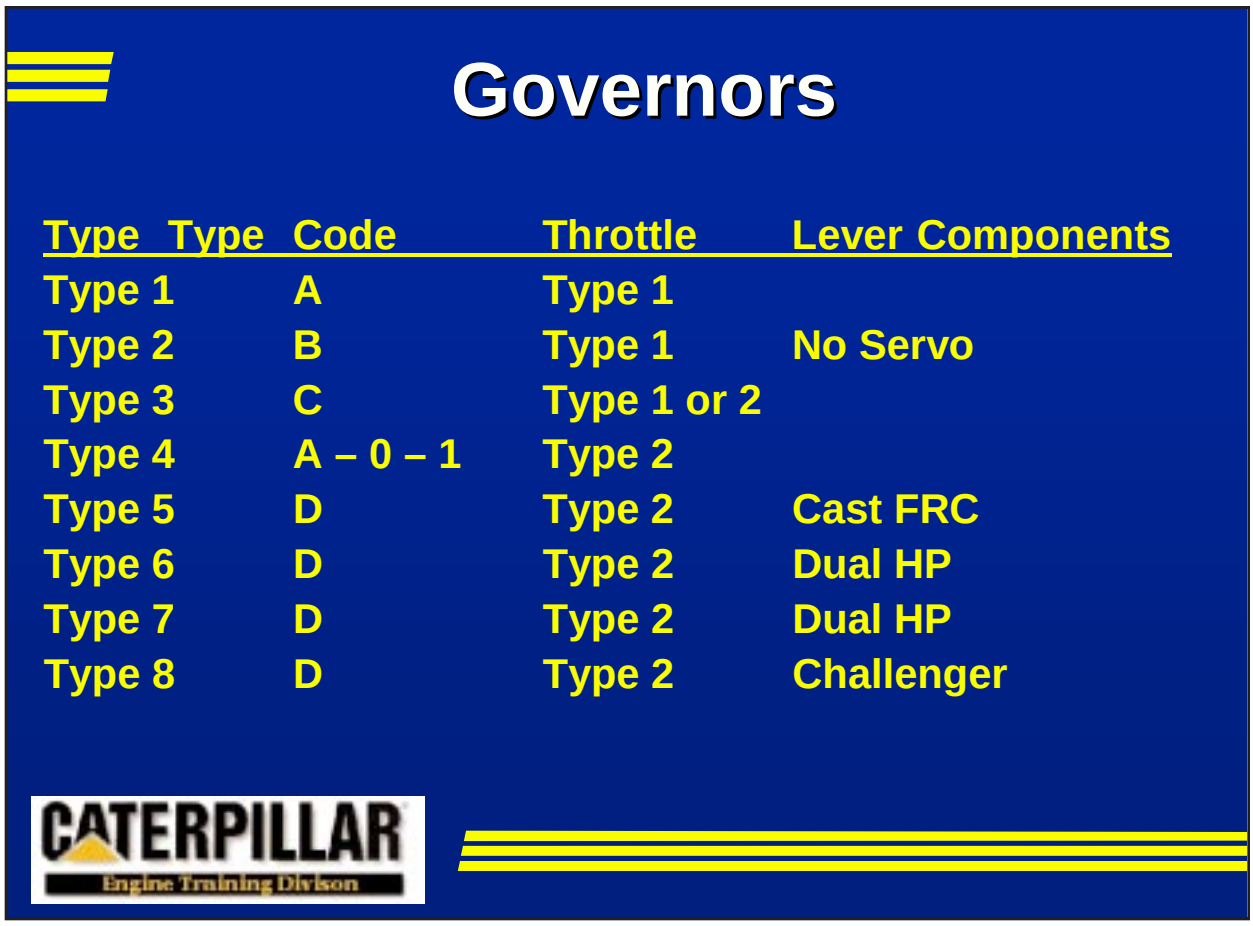
Floating fulcrum

Bench testing

The governor is mounted high on the left side on the front housing of the engine. It is driven by the cam gear in the front gear train. Fuel rate and engine speed are controlled by linkage connected to the injector rack.

The governor is a flyweight type, full range, with a floating fulcrum linkage which allows for a small package. Additionally, a speed sensitive torque cam provides torque curve shaping for specific high volume applications.

The governor is bench set dynamically. Power is set at the rack control linkage on the cylinder head using a dial position indicator. All adjustments are made on this control linkage which is sealed at the factory, the governor is also sealed after bench setting and is not to be adjusted except on the governor bench.


Governors
Type Type Code Throttle Lever Components
Type 1 A Type 1
Type 2 B Type 1 No Servo
Type 3 C Type 1 or 2
Type 4 A – 0 – 1 Type 2
Type 5 D Type 2 Cast FRC
Type 6 D Type 2 Dual HP
Type 7 D Type 2 Dual HP
Type 8 D Type 2 Challenger
CATERPILLAR
Engine Training Division

SLIDE 58

Governor types

Type codes

Lever types

Housings

There are eight types of governors used on the 1.1 and 1.2 liter engines. Each of the governors can be identified by the type code after the serial number and specific components.

Type I governors can be identified by a the type code “A” following the serial number, and a spring return throttle lever.

Type II governors can be identified by the type code “B” following the serial number and a spring return throttle lever. Type II governors were only used on 3114 engines and do not use a servo for controlling rack movement. Type II governors also have four flyweights.

Type III governors can be identifed by the type code “C” following the serial number. Type III governors may have a spring return throttle lever, or a press on type lever.

Type IV governors can be identified by the type code “A” or the numbers “0” or “1” following the serial number. Type IV governors

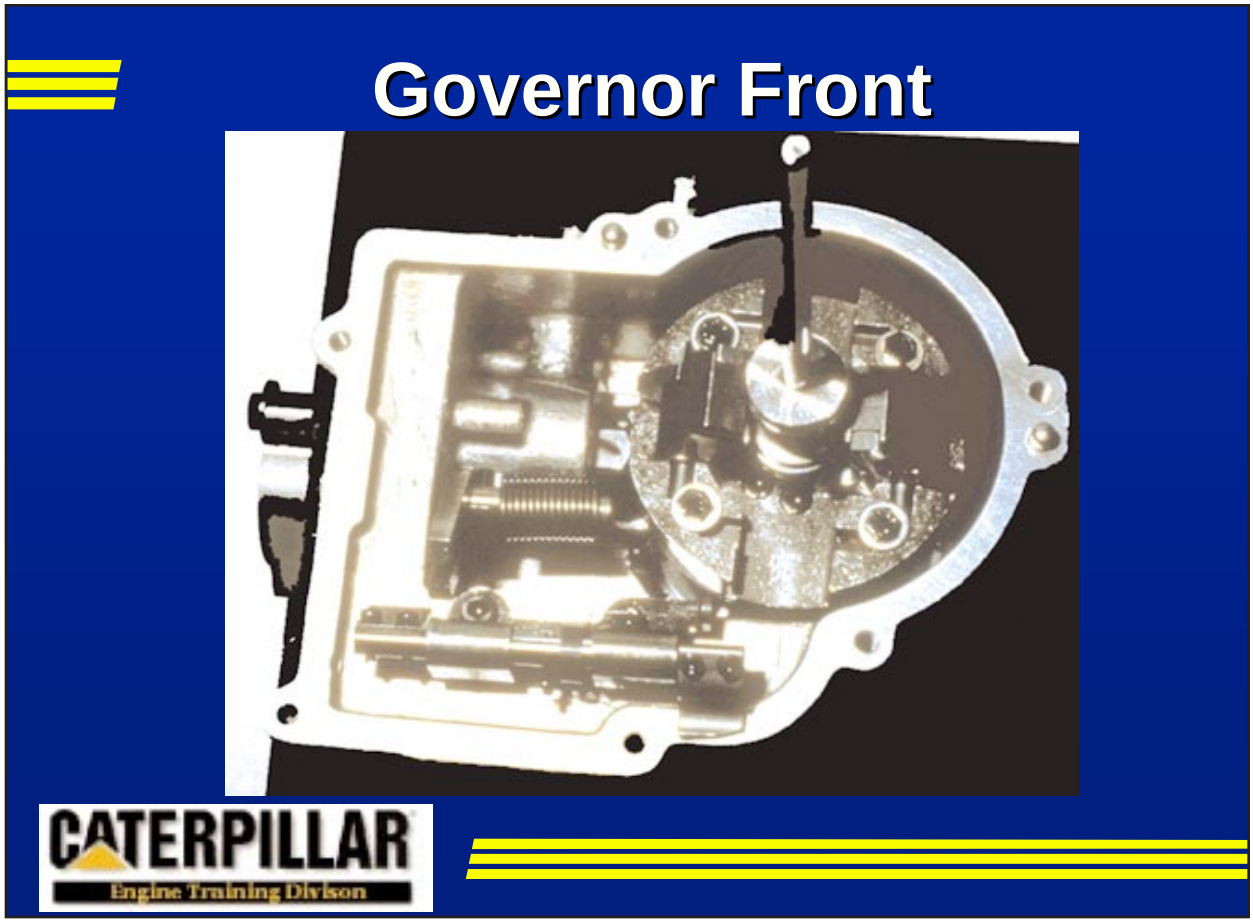
will have a press on type throttle lever.

Type V governors can be identified by the type code “D” following the serial number and a press on type throttle lever. Type V governors also have the fuel ratio control cast into the governor housing.

Type VI governors will also have type code “D” following the serial number, press on type throttle lever and cast in fuel ratio control housing. Type VI governors, sometimes referred to as dual horsepower governors will have a dual horsepower mechanism on the side of the governor.

Type VlI governors will also have type code “D” following the serial number, press on type throttle lever and cast in fuel ratio control housing. Type VII governors, sometimes referred to as dual horsepower governors will have a dual horsepower mechanism on the side of the governor.

Type VIII governors are used on the Challenger Tractors.



SLIDE 59

Gear driven

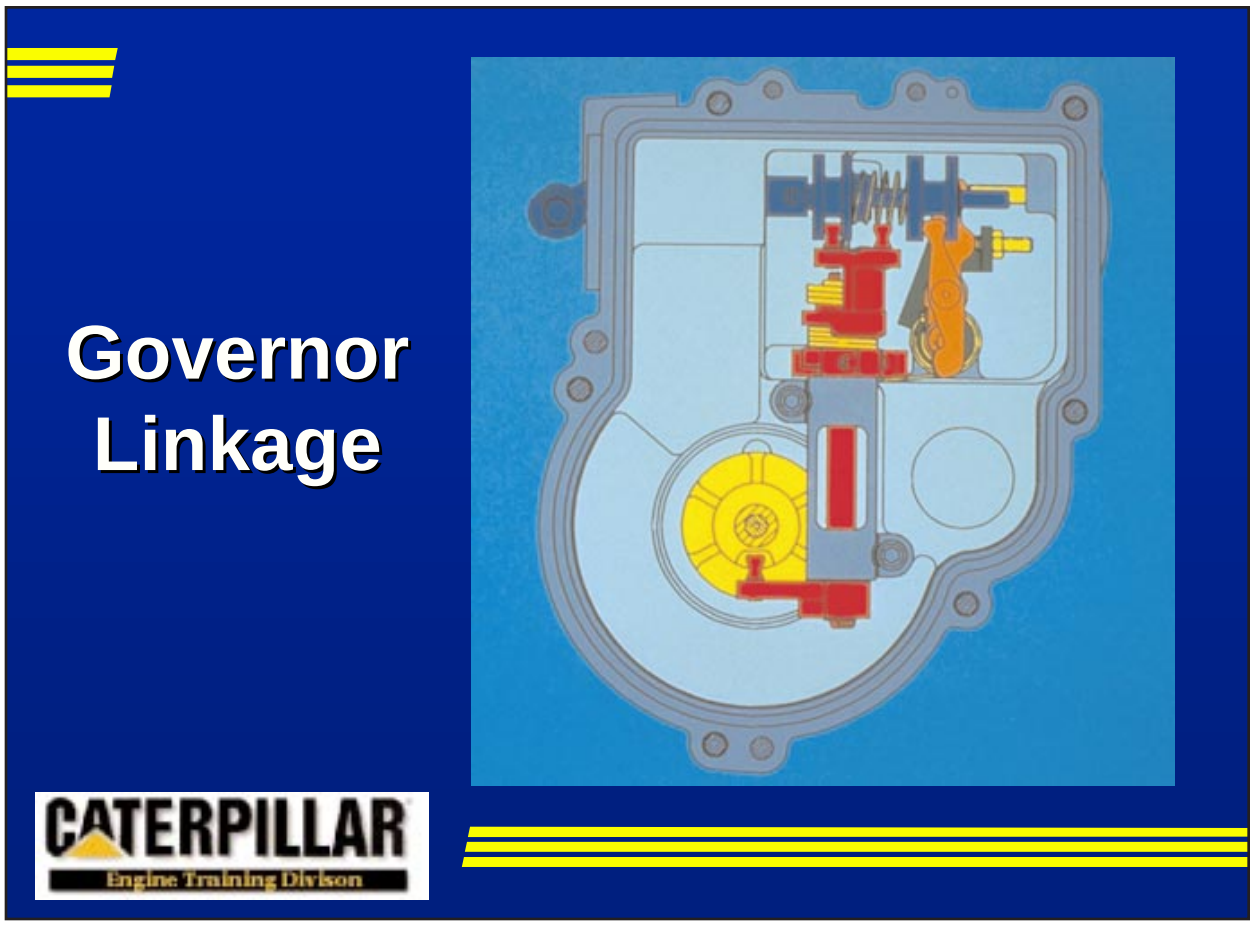
Flyweights

Riser

Spring pack

Governor spring

The governor is gear driven from the engine camshaft. This drives the flyweights inside the governor. The flyweights move the riser on the riser shaft. The movement of the riser on the shaft is opposed by a spring pack. Engine speed and spring force determine the location of the riser.



SLIDE 60

Riser lever

Pivot shaft

Torque cam

Governor output shaft

Speed changes

Throttle lever

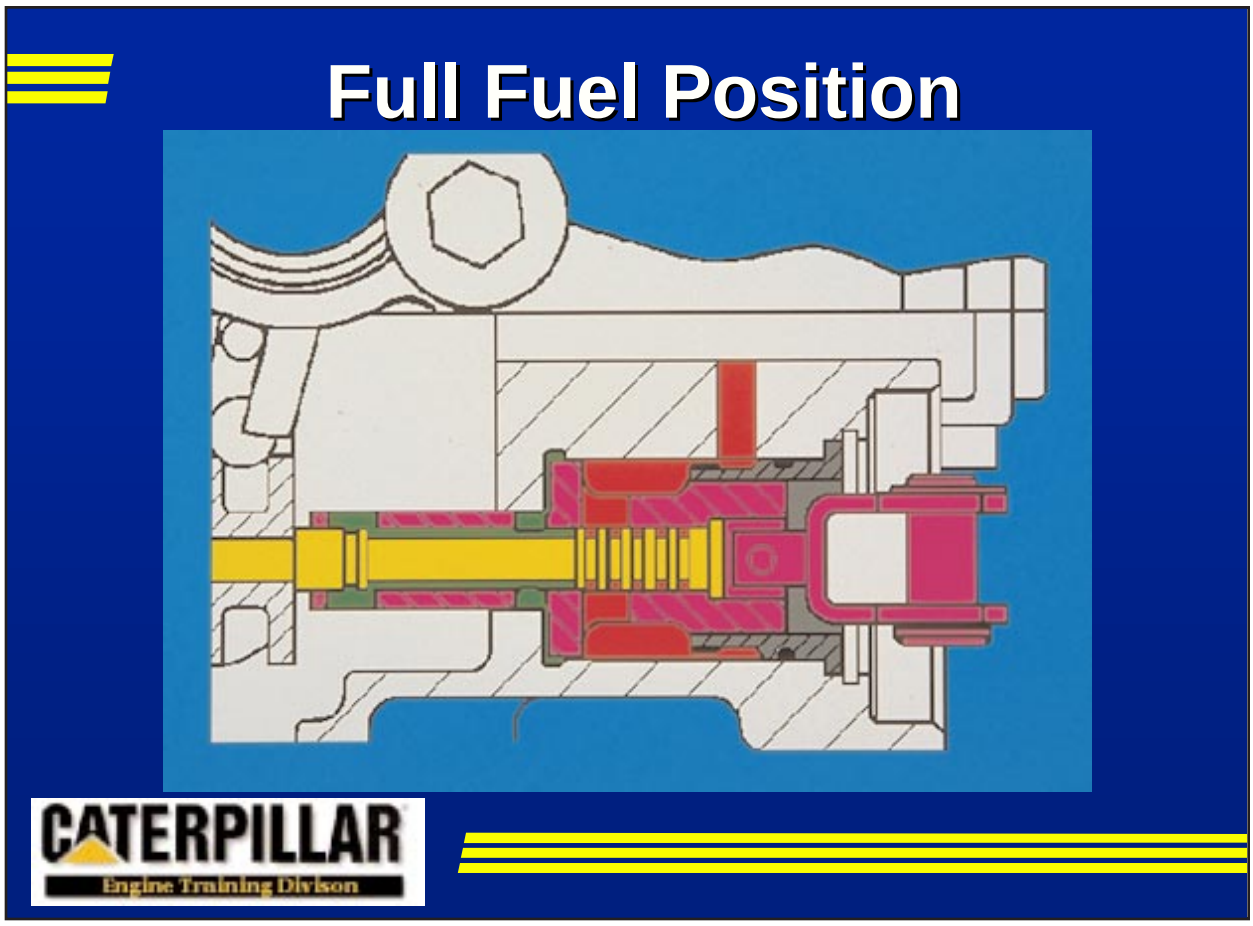
The riser moves the riser lever, which rotates the pivot shaft and torque cam (red). The torque cam moves the torque lever (orange) to adjust the governor output shaft (blue).

The operator selects the desired speed through the throttle lever. (shown in the previous slide) The throttle lever and governor output shaft are connected by the fulcrum lever, which is pinned to the pivot lever. This connection provides the operator with a direct communication to the governor output.

As the engine speed changes, the fulcrum lever moves to change the governor output to a new stable condition. The same condition occurs when the operator changes the position of the throttle lever.

The governor limits the fuel injected into the combustion chamber when rated load or a lug condition is reached. When this condition occurs, the output shaft is in the maximum FUEL ON position. The torque lever has rotated about a pin on the limit lever until the torque lever contacts

the torque cam. If more load is applied to the engine in this condition, engine speed will decrease. This decrease will be felt by the flyweights, causing the riser to rotate the riser lever and the pivot shaft to a new position. Since the torque cam is fixed to the pivot shaft, different torque characteristics can be achieved by changing the profile on the torque cam.



SLIDE 61

Servo

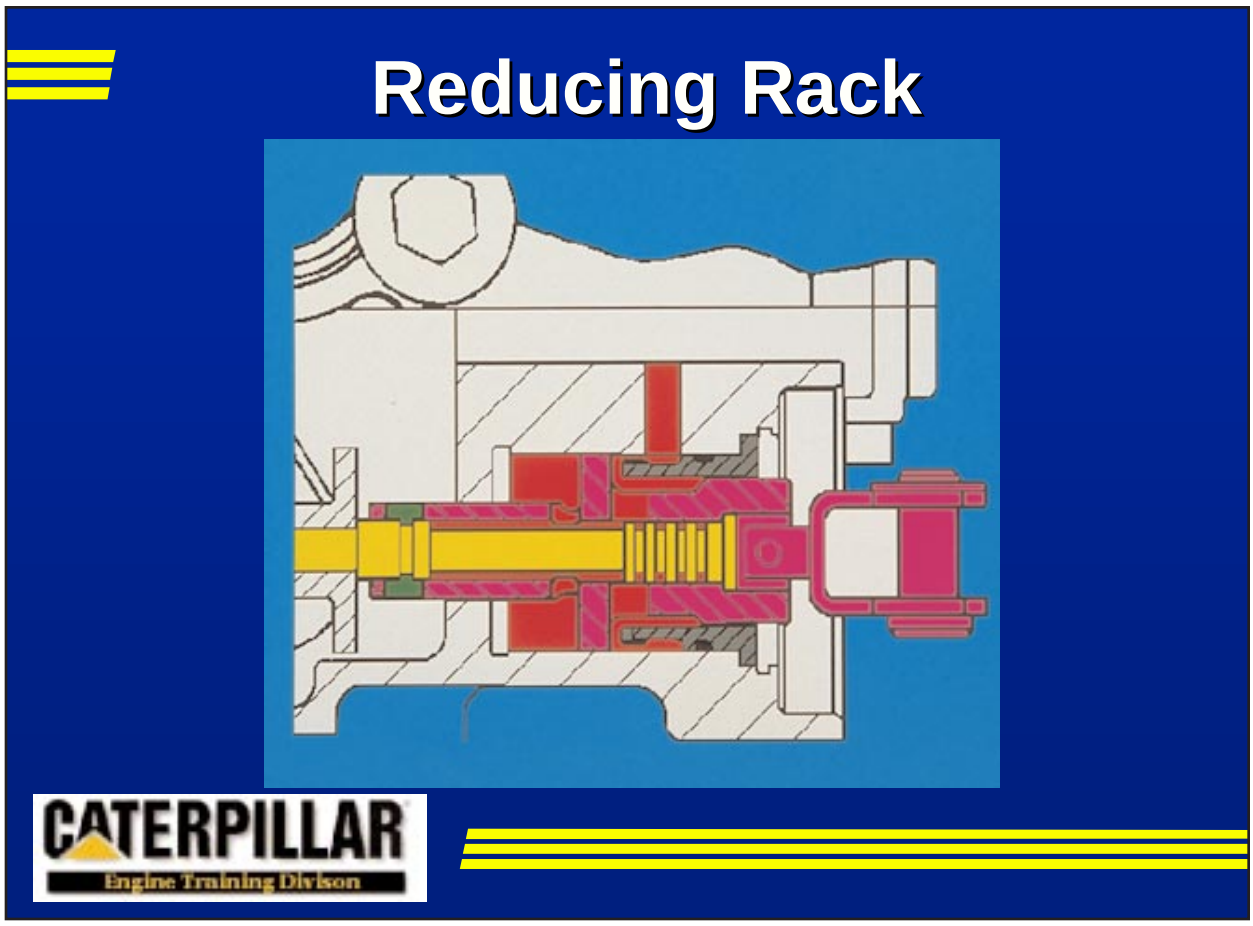
Governor types

Servo

Fuel on direction

Movement of the governor output shaft is controlled by the servo on governor types 1, 3, 4, 5, 6, 7 and 8.

When the governor moves in the fuel on direction, the valve moves to the left. The valve closes the path for pressure oil to go to drain. At the same time, the valve opens a path to drain to allow the oil behind the piston to escape. Pressure oil pushes the piston and clevis to the left.



SLIDE 62

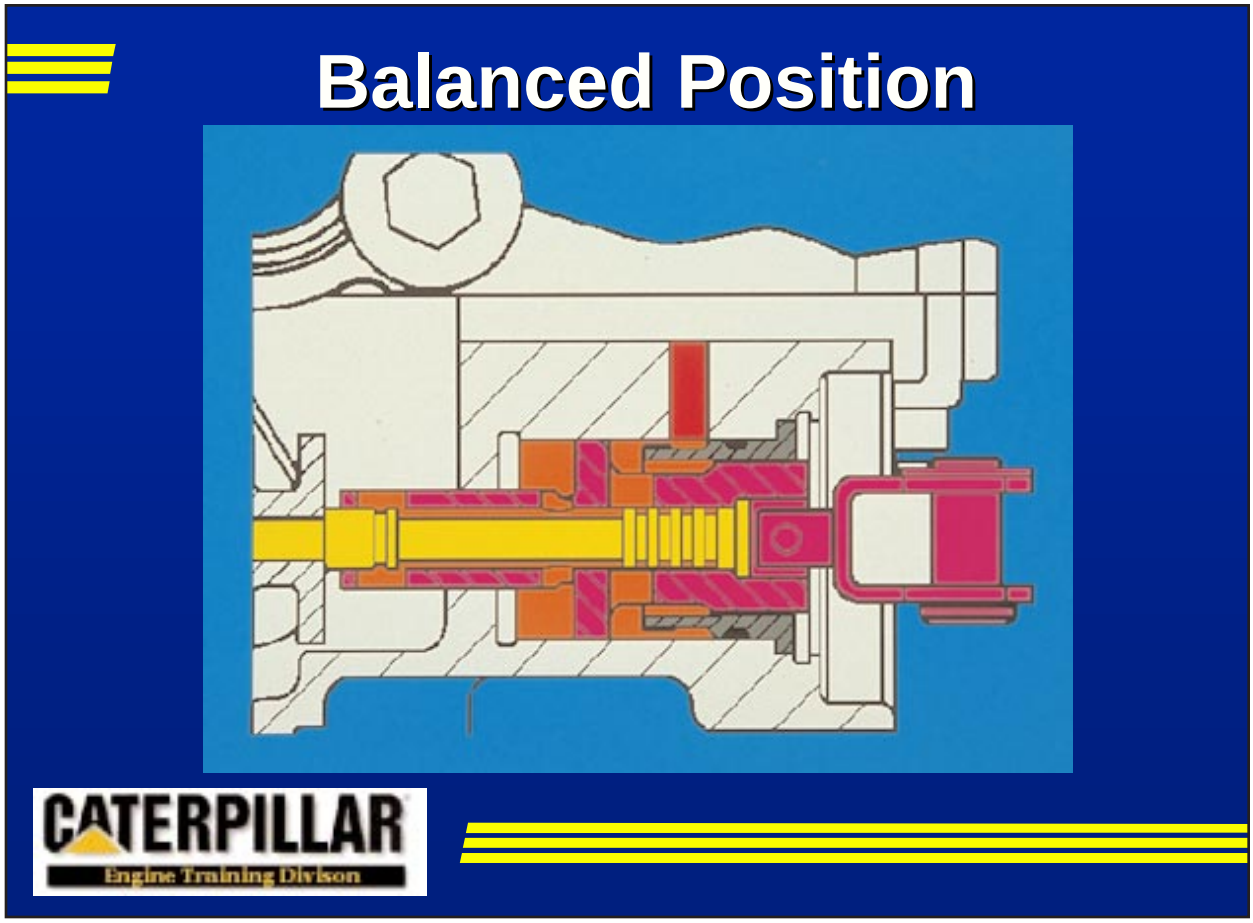
Fuel off

Valve movement

Surface area

Piston movement

When the governor moves in the fuel off direction, the valve moves to the right. The valve closes the path to drain, and opens a path for oil to flow behind the piston. Pressure oil is now on both sides of the piston. The surface area is greater on the left side of the piston than on the right side. The force of the oil pressure will also be greater on the left side of the piston and moves the piston and clevis to the right.



SLIDE 63

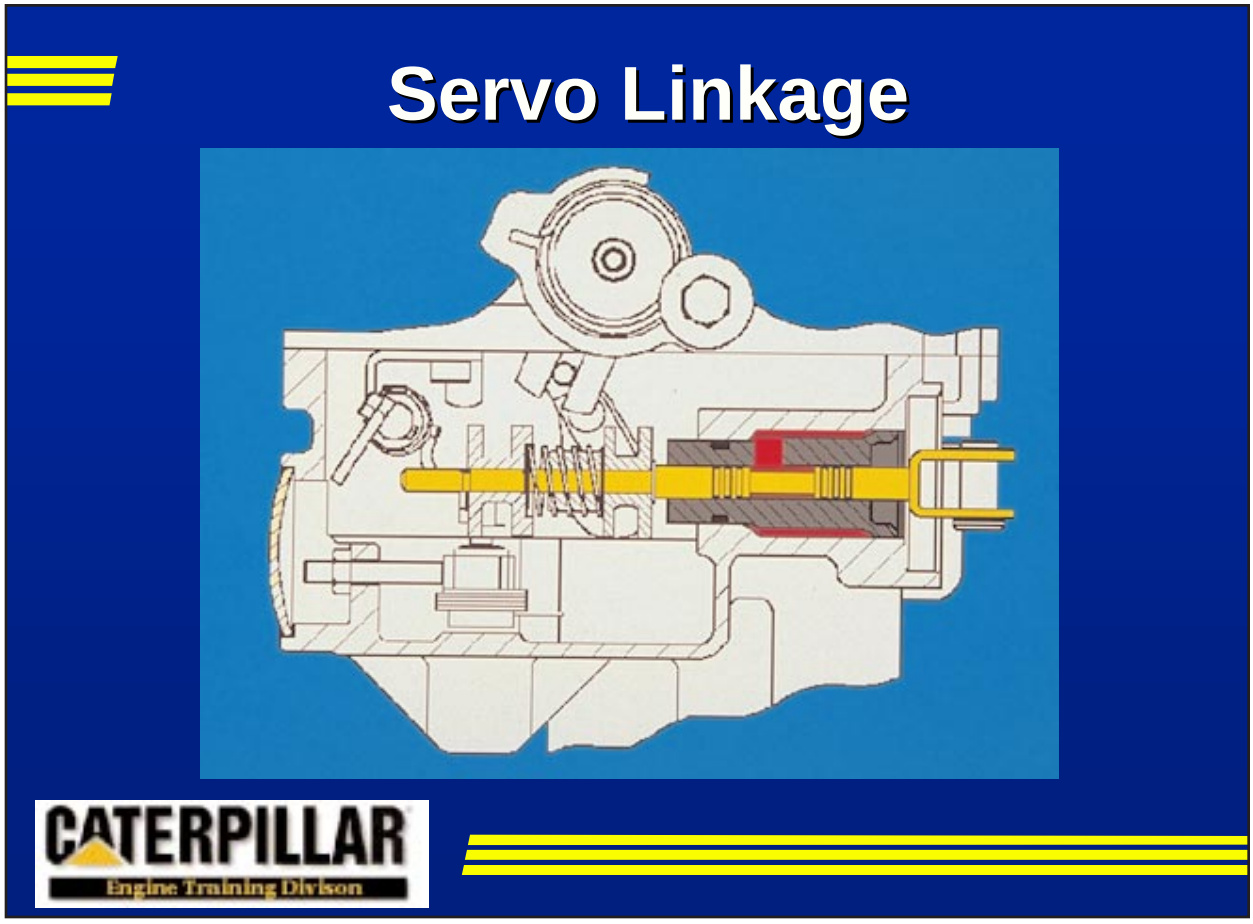
Governor spring

Flyweights

Balanced

Oil path

When the governor spring and flyweight forces are balanced and the engine speed is constant, the valve will stop moving. Pressure oil will continue to push the piston to the left until the path to drain is opened. Oil will now flow along the valve to drain. With no oil pressure on the piston, the piston and clevis stop moving.



SLIDE 64

Type II governors

No servo

Four flyweights

As mentioned earlier, type II governors do not use a servo to control rack movement. Instead, the type II governors used four flyweights to control the rack movement. The use of four flyweights eliminated the need for a servo assist when used on a 3114 engine.

SLIDE 65

Assembly adjustments

Riser spool shimming

Zero indicator

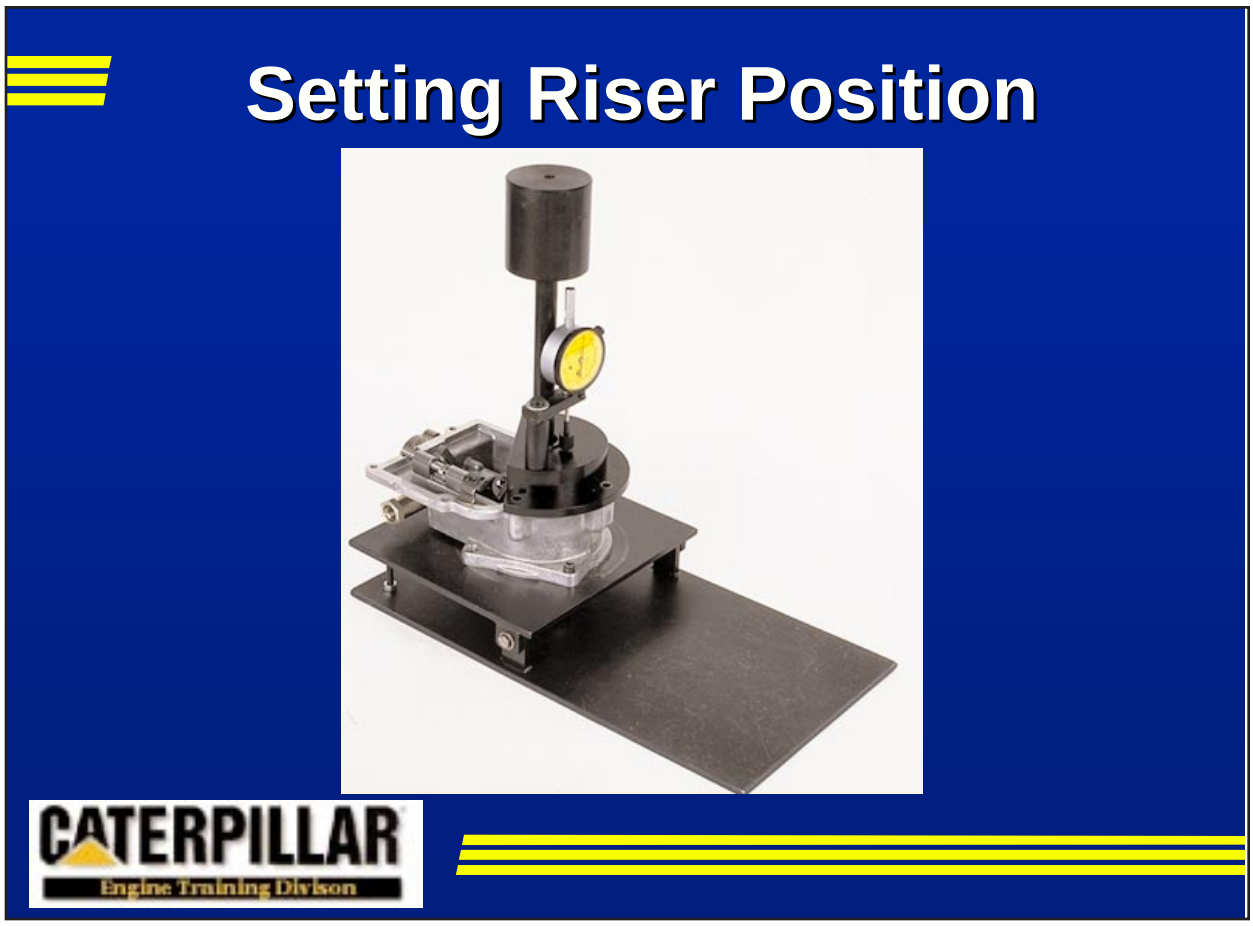
During assembly of the governor, there are several internal adjustments that must be made in order for the governor to perform properly when running on the calibration bench. The first of these adjustments is riser spool shimming. This procedure positions the riser spool in the proper location when the flyweights are completely compressed.

Before shimming the riser spool, the indicator must first be zeroed using a gage block. Assemble the shim adjustment tool (1U7309), calibration plate (1U7312), and gage block (1U7313). Position the gage block on the calibration plate so that the longer dimension is vertical. Install the dial indicator (6V6106) into assembled tooling. Lift up on knurled portion and carefully lower ball onto the gage block. There is a notch on top of the knurled handle that aligns with the stem and ball. Be sure only the ball touches the gage block. An incorrect setting will result if the stem touches the gage block. Raise or lower the indicator in the fixture until all of the pointers read zero or if using a digitial indicator, zero the indicator.

SLIDE 66

Assemble riser

Assemble the riser with shims, bearing, races. It is not necessary to install the retaining ring while making this adjustment. Install the riser on the riser shaft with the bearing races on the flyweights.



SLIDE 67

Install tooling

Indicator difference from zero

Install the tooling on the governor front housing. Put the weight on top of the riser to compress the shims. Lift up on the knurled knob and place ball into the riser slot surface and read the indicator. The dial indicator difference, (±) from zero, equals the thickness of shims to add or remove until the reading is 0 ± .08 mm (0 ± .003 in). Once the correct number of shims has been determined, remove the riser and install the retaining ring.

SLIDE 68

Torque cam adjustment

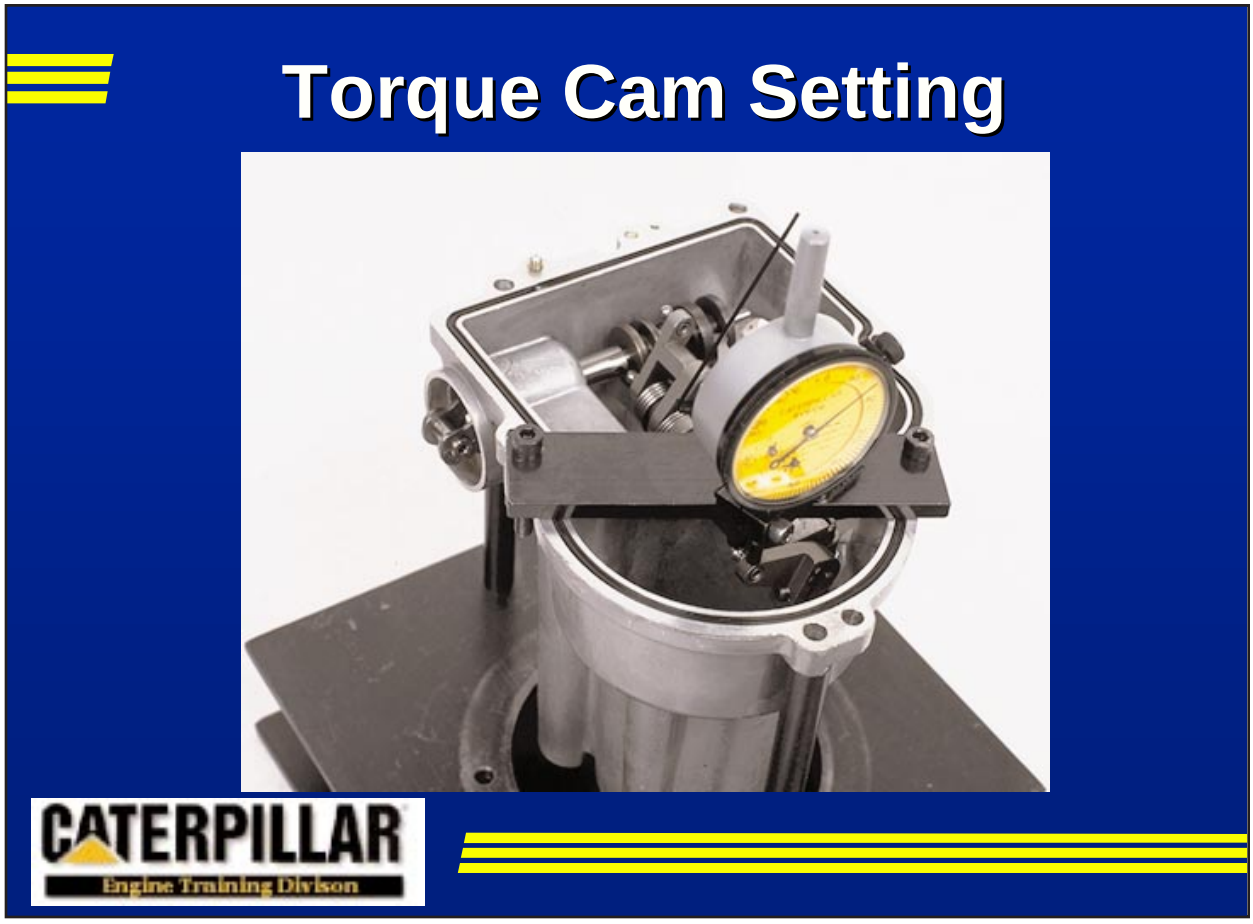
Types 1 through 4

Torque cam lever

On types one through four governors, a torque cam adjustment must be made prior to assembly. This adjustment can be made after the rear housing is assembled and mounted on the stand. To make this adjustment, the seal shown in the illistration, should be removed.

There is no internal torque cam adjustment on types five through eight governors.

Grasp the riser lever and rotate clockwise until torque cam lever clears torque cam lever shoulder in torque cam. Move the torque cam lever over the shoulder in torque cam. Rotate the riser lever counter clockwise until the torque cam lever contacts the shoulder in the torque cam.



SLIDE 69

Torque cam adjustments

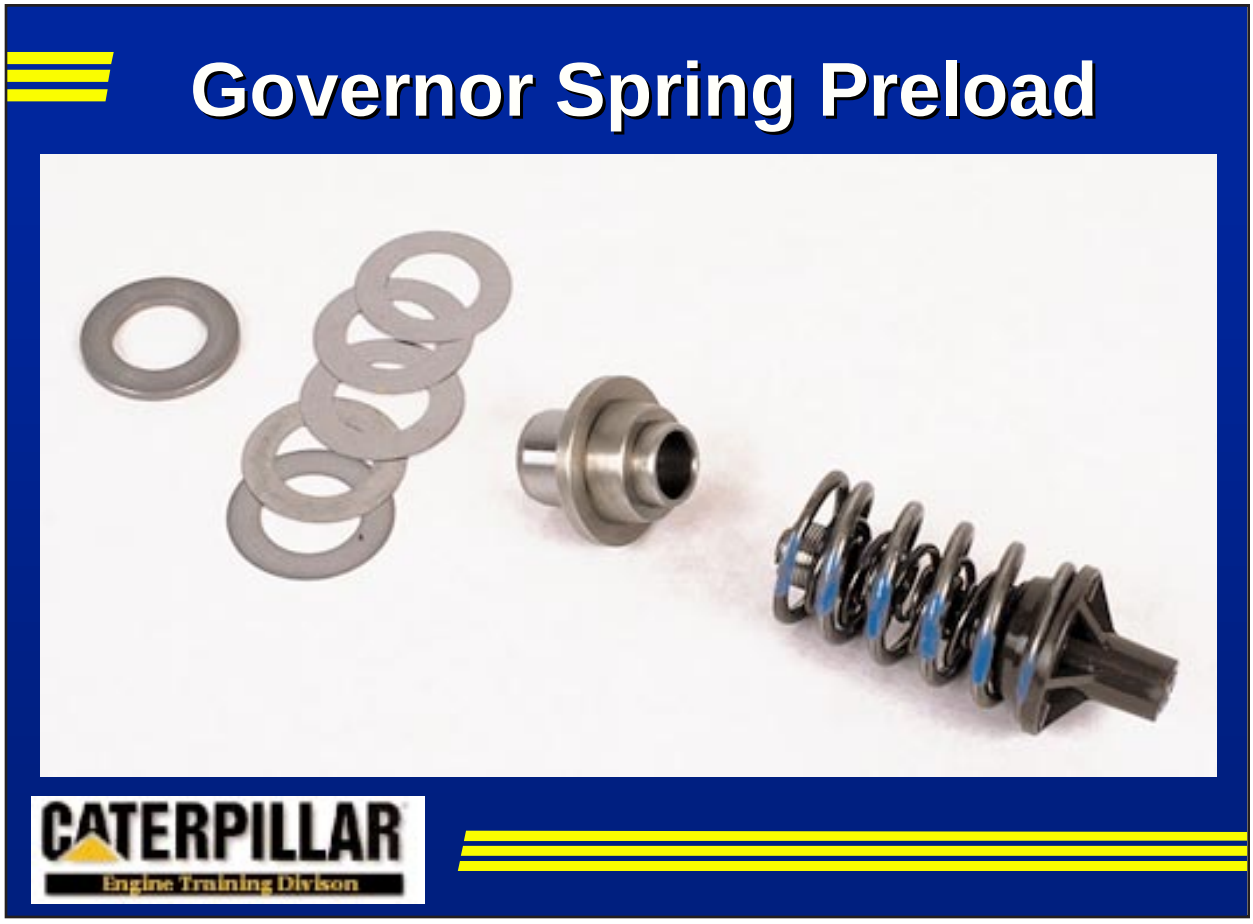
Install tooling

Zero indicator

TMI

Using two bolts furnished in the 1U7315 tool group, install the 1U7310 fixture onto the housing. Install the 5S8086 contact point into the 6V6106 dial indicator or digitial indicator. Install the dial indicator into fixture until it bottoms out. The tip of the dial indicator should rest on the edge of riser lever. Place the 1U7311 allen wrench furnished in the 1U7315 tool group into torque cam setscrew. Using the wrench as a lever, rotate the torque cam clockwise until riser lever swivel contacts the post on the fixture. Continue rotating clockwise, winding up the torsion spring. Holding the wrench in this position, move the dial indicator in the fixture until all of the pointers read zero. Tighten the set screw to hold the dial indicator in this position. Use the wrench as a lever and rotate the assembly counter clockwise until the torque cam and torque cam setscrew break apart. Release the wrench slowly until the setscrew again makes contact with the Torque Cam. Release the wrench. The reading on the dial indicator will show the torque cam dimension. Refer to TMI for the correct dimension. If necessary, adjust

the setscrew until correct dimension is shown on the dial indicator.



SLIDE 70

Governor spring preload

The governor spring preload must be checked on all governor types to insure proper governor operation. Shims can be added or removed from the governor spring to adjust the governor spring preload.

After inspection assemble spring seat assembly and springs onto riser shaft with springs facing up. Install governor shims (if equipped), rear spring seat (if applicable), shims, and spacer. If governor is equipped with dashpot piston assembly, be sure the dashpot piston assembly is piloted in the rear spring seat.

SLIDE 71

Governor spring preload

Install tooling

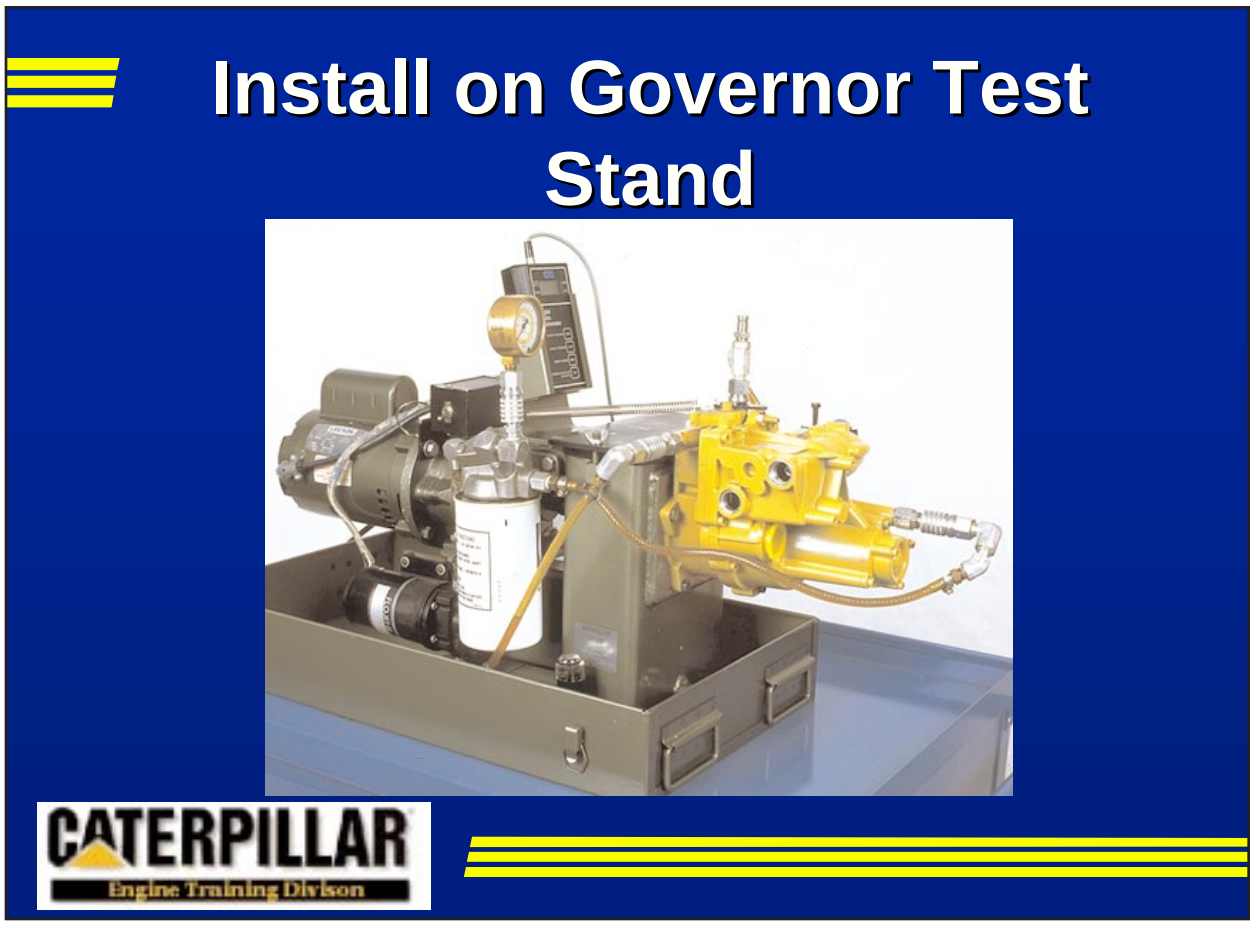
Add or remove shims

Refer to TMI

With the O-ring seal removed, lightly lubricate the housing bore with engine oil and loosely fit the rear cover assembly into place.

Remove the fitting and screen assembly in the housing, where engine oil is supplied to the governor. Install the 9S0229 contact point into the 6V6106 dial indicator. Install the dial indicator into the 1U7308 governor spring shim adjustment tool. Use a 1D4556 bolt to install the assembled tooling into housing, where fitting and screen assembly were removed. Make sure the dial indicator is on the center of the rear cover. Push down on rear cover assembly until it makes contact with the governor housing and then zero the indicator. Release the cover and rotate it approximately 1/4 turn as the spring pushes up, then read the indicator. Refer to TMI for the correct spring preload dimension according to the governor group number. Add or subtract shims to achieve the correct spring preload dimension. After setting, remove tooling and cover assembly. Install the O-ring seal on the cover assembly. Put the cover in position on the governor housing and install

the bolts. Install the engine oil supply screen assembly and fitting.



SLIDE 72

Governor adjustments

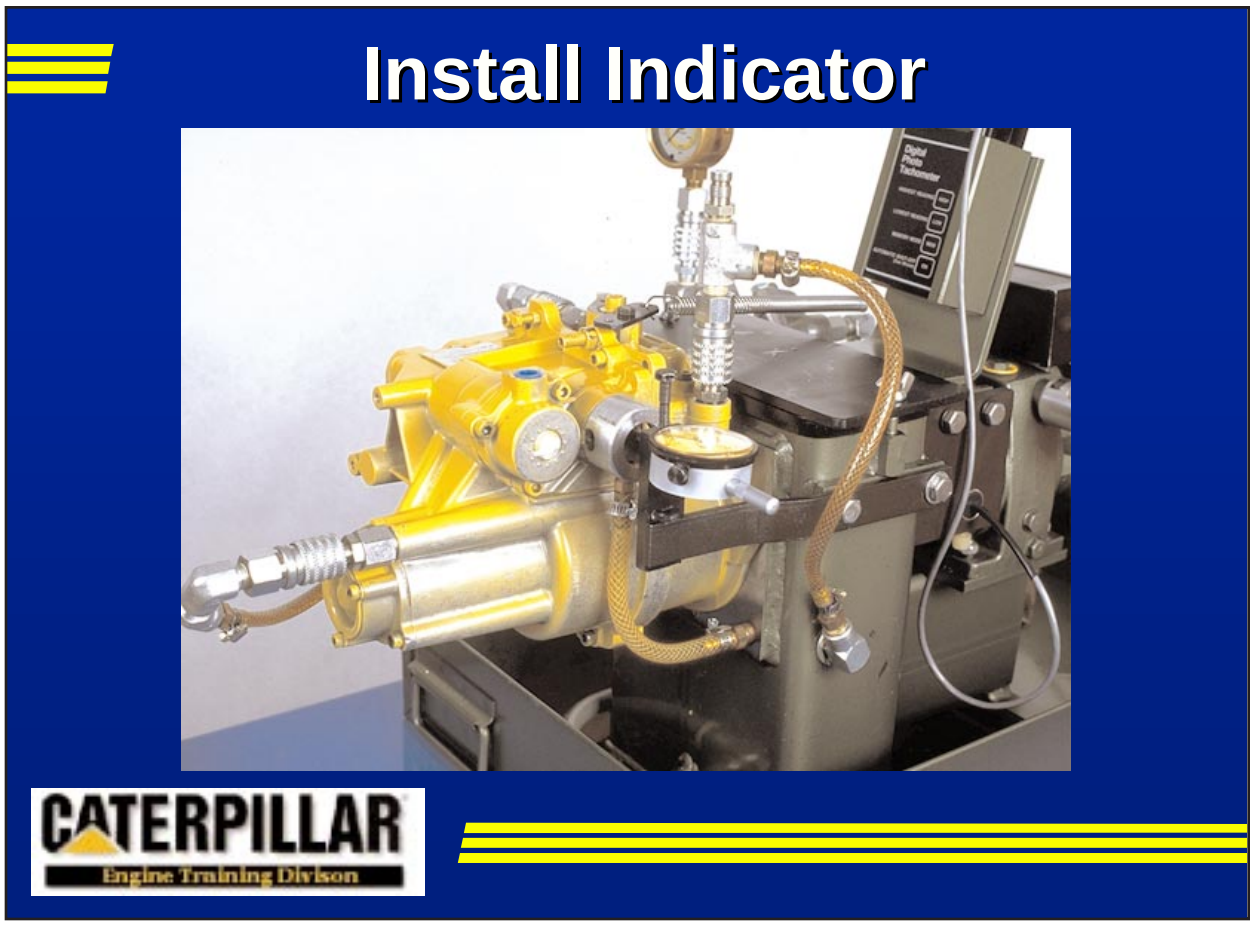
Low idle

No set point measurement

Bench maintenance

All of the adjustments for the governor must be done on the governor calibration bench. If the low idle is not satisfactory, the locknut can be loosened and the low idle can be set in chassis by turning the adjusting screw. After making the adjustment, tighten the locknut. There is no set point measurement capability. The full load speed is adjusted on the test bench. The calibration bench weighs approximately 150 pounds. It has a 50 or 60 cycle, 1/2 hp electric motor and digital tachometer, Ten weight oil is used to lubricate the governor during testing.

Proper maintenance must be done on the bench prior to use. Check the oil in reservoir and variable speed drive. Install the governor on the calibration bench. Install three fittings (fuel in, fuel out, and oil). Install four fittings if governor is equipped with fuel ratio control. Connect the oil lines to fittings. Install the lever on the throttle lever and install return spring.



SLIDE 73

Calibration dimension

Special procedure

More than 9.00mm

Put a 1U8815 contact point on the stem of the 6V6106 dial indicator. Install the dial indicator into bracket. The dial indicator is used for setting the load stop adjustments, and must be set at the calibration dimension (8.00 mm on most governors) before bench testing.

If the load stop measurement is more than 9.00 mm a special procedure must be used for setting the dial indicator calibration dimension. Refer to the Bench Preparation Procedure - Setting the Governor Load Stop Dimension For More Than 9.00 mm in the Service Manaul for 3114, 3116 & 3126 Engine Governors, Form No. SENR6454.

SLIDE 74

Type I through IV governors

Load stop adjustment screw

FRC adjustment screw

Low idle

Throttle stop

The top screw shown here is load stop adjustment screw on type I through IV governors.

The bottom screw is the adjustment for the fuel ratio control on type I and IV governors.

The low idle and throttle stop adjustment screws are located on top of the governor housing.

SLIDE 75

Type V and VI governors

Load stop adjustment

FRC adjustment

Low idle

Throttle stop

On type five and six governors, the screw shown on the lower left is the load stop adjustment. The one on the upper right is for the fuel ratio control.

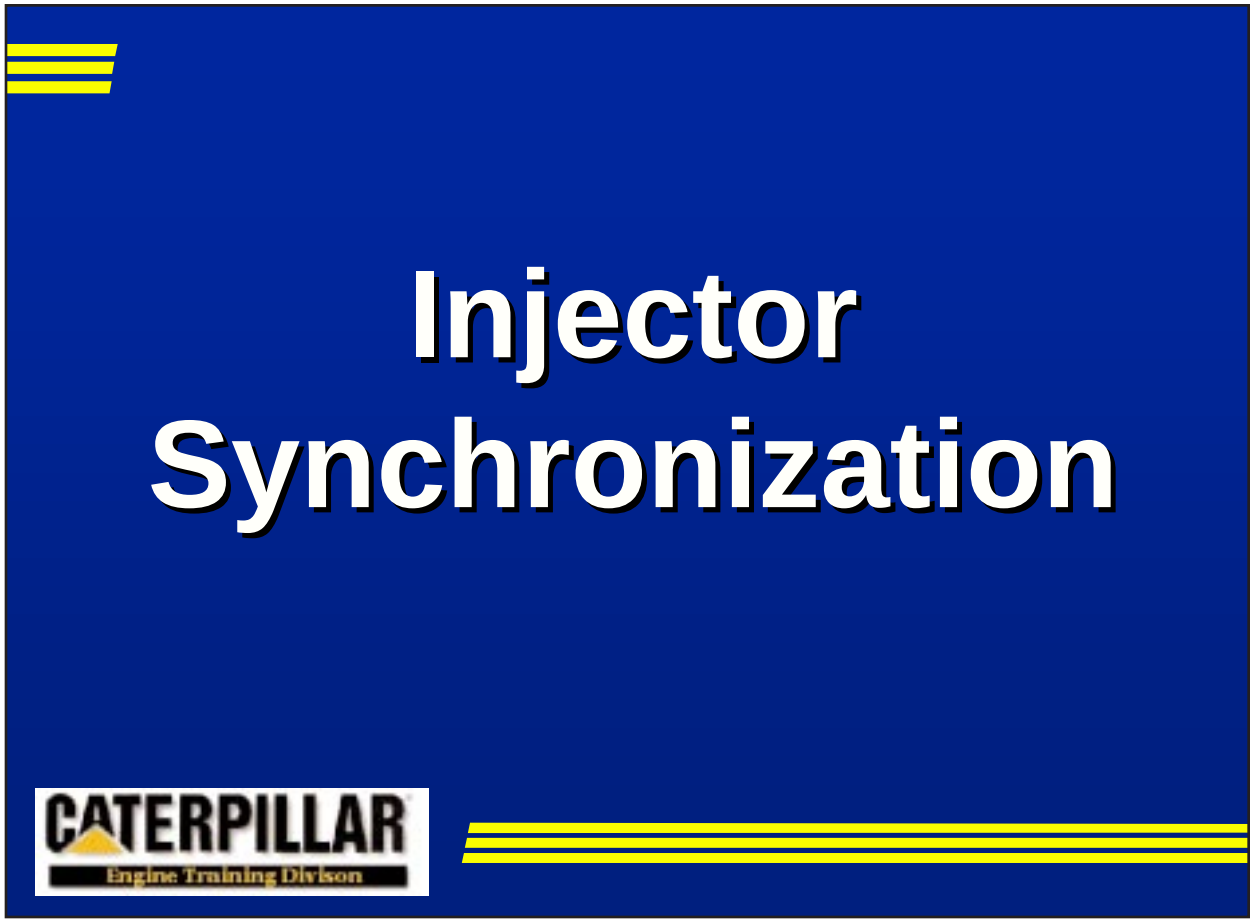
The low idle and throttle stop adjustment screws are located on top as with the earlier governors.

SLIDE 76

Throttle stop

Low Idle screw

The throttle stop screw is the one shown lower in the picture while the low idle screw is the upper one.



SLIDE 77

Injector synchronization

Reference position

Number 1 cylinder

Injector synchronization is the setting of all injector racks to a reference position (the No. 1 injector). This ensures each injector delivers the same amount of fuel to each cylinder. This is done by setting each injector rack to the same position while the control linkage is in a fixed position (called the synchronizing position). The control linkage is at the synchronizing position when the injector of the No. 1 cylinder is at 3.5 mm which is set with a positioning block. Since the No. 1 injector is the reference point for the other injectors, no synchronizing adjustment is made to the No. 1 injector. Always synchronize an injector when it has been removed and reinstalled or replaced. If the No.1 injector is reinstalled or replaced, all injectors must be synchronized

SLIDE 78

Shutoff solenoid

To synchronize the fuel injector rack, either pull out and latch the center rod of the solenoid or remove the solenoid. This allows the injector rack control linkage to move freely during synchronization.

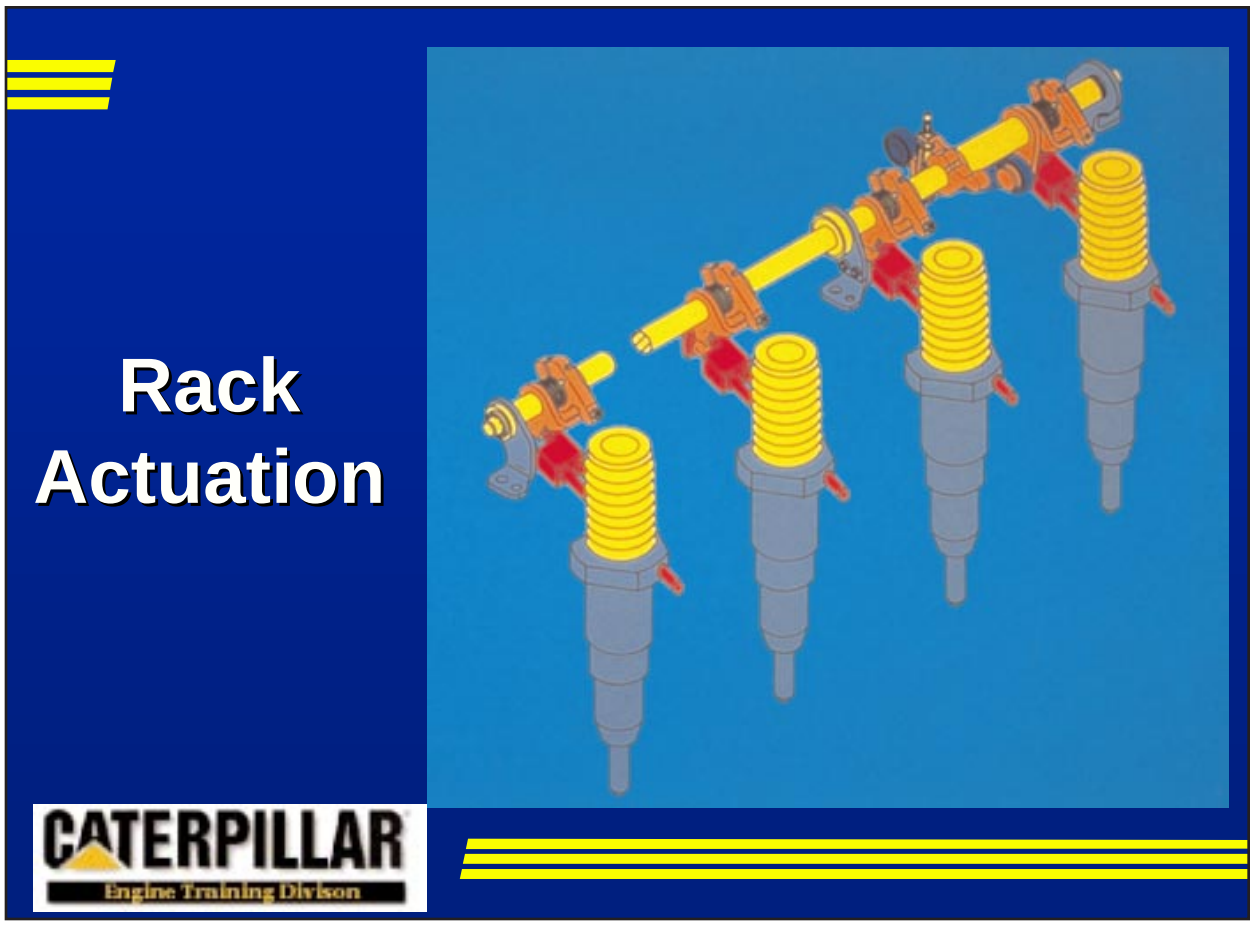
SLIDE 79

Preparation for synchronizing the injectors

Rocker arm assemblies

To prepare for injector synchronization, remove the valve cover and rocker arm assemblies for No. 1 unit injector. The injector synchronization can be done with the rocker arm assemblies removed or left in place.

If the rocker arm assemblies are removed, be sure to hold the assemblies together. Only one end of the rocker arm assembly is pinned to the rocker stand.



SLIDE 80

Each injector rack is activated by a rack control assembly. All of the injectors need to be equal with their injector or the engine would run rough. This is done by adjusting all of the injectors to the to the same rack position as the number 1 injector. This procedure is called rack synchronization.

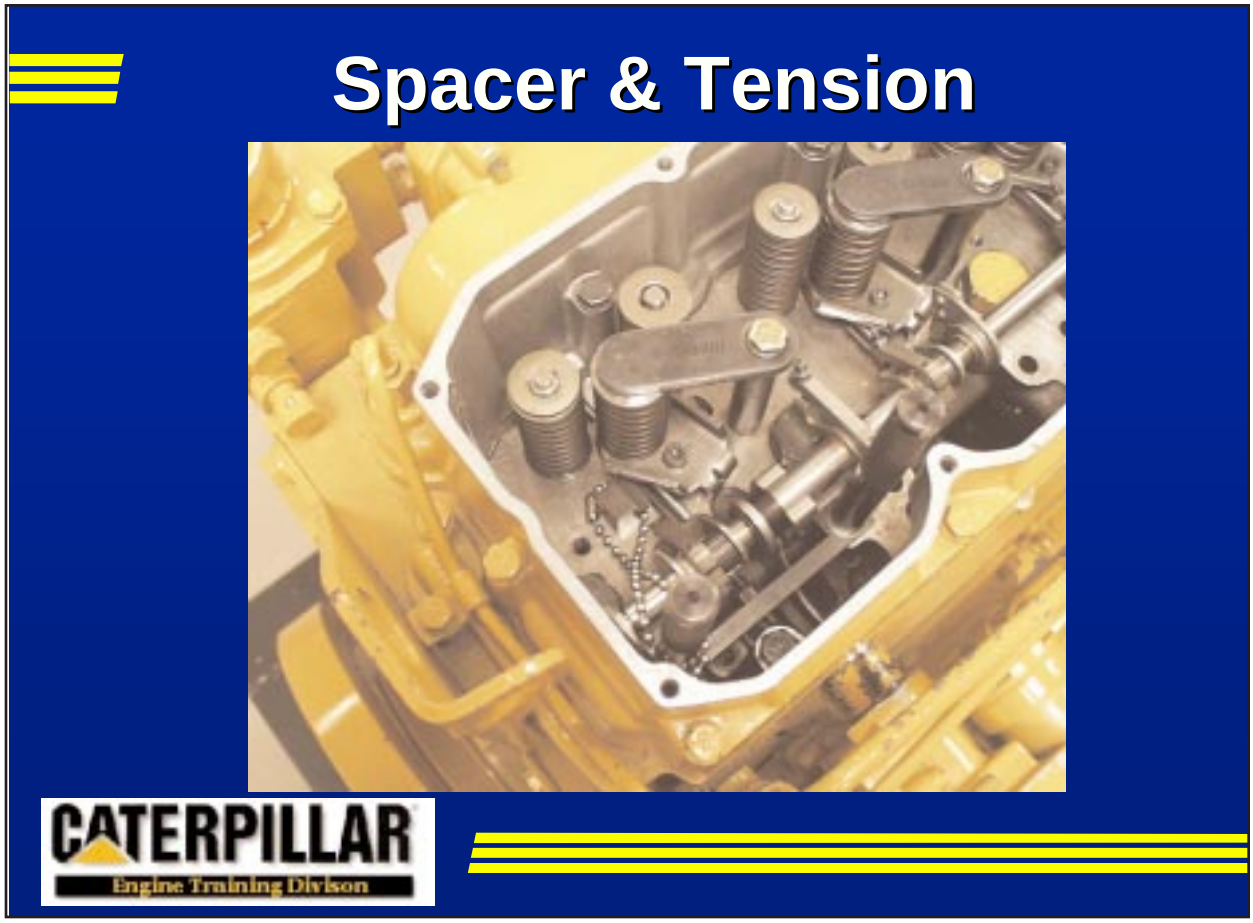
Each of the injectors actuation mechinism has an adjusting screw except the number 1 which is the “master” of the group. Number 1 injector is set and locked to a known rack position and the rest are then adjusted to that position.

The number one injector is linked to the governor using the fuel setting procedure covered later in the presentation

SLIDE 81

Install spring compressors

If the rocker arm assemblies are removed, install the 1U6675 spring compressor on the unit injector to allow free movement of the racks. Apply a small amount of clean engine oil to the top of the injectors. Install an injector spring compressor on each of the injectors. Compress the injector by tightening the bolt . Tap lightly with a soft hammer on the spring compressor to ensure free movement of the injector rack bar.



SLIDE 82

Injector synchronization using the 128-8822 tool group

Install the fixture group

Install gage block

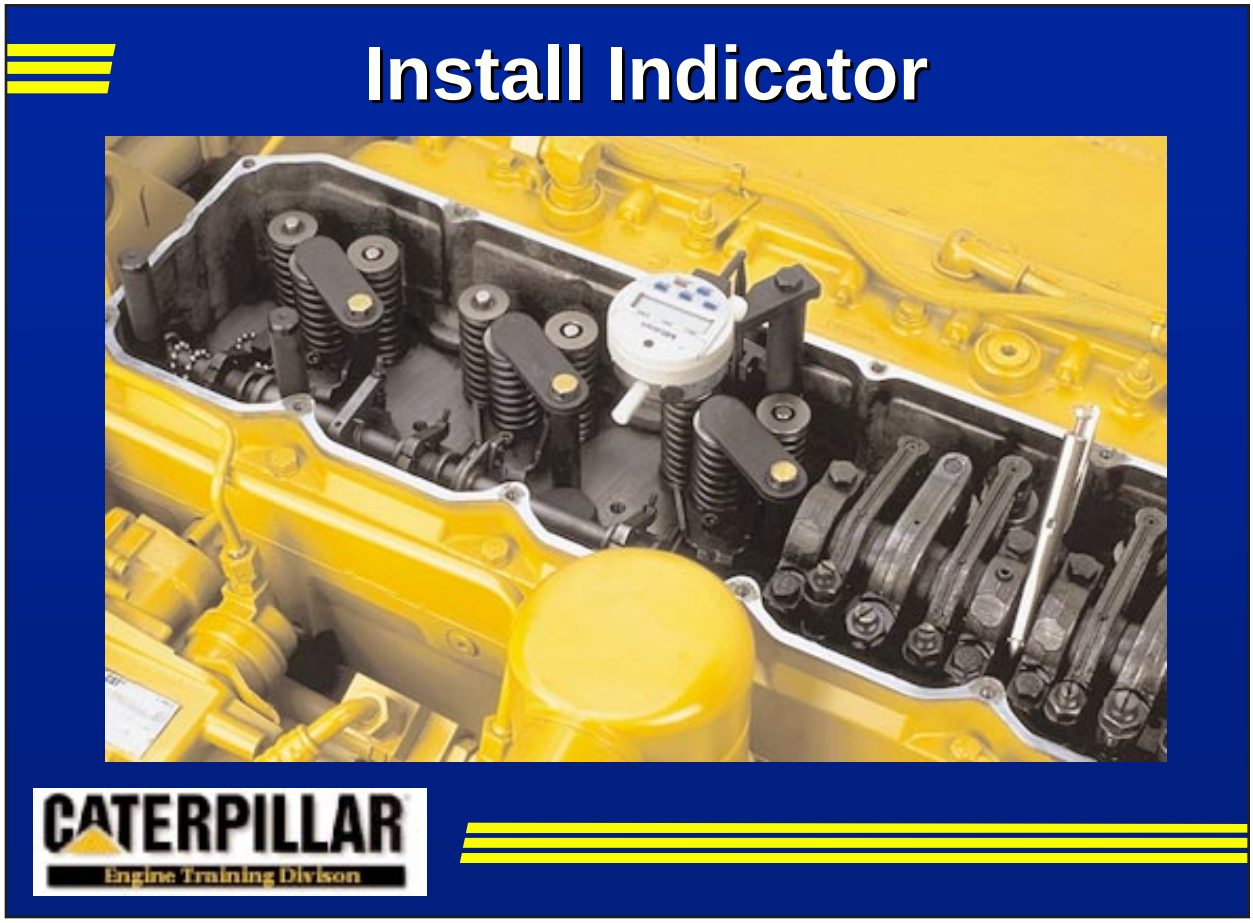
Injector synchronization using the 128-8822 tool group.

Remove the valve cover, and rocker arm assembly for number one cylinder. If desired, remove the rocker arm assemblies for the injectors to be synchronized. Be sure that the rocker arm assemblies are held together if they are removed.

Move the number one injector rack to the full fuel off position. Install the 128-9640 fixture group on cylinder head at the number one cylinder. Be sure that the detent clears the rack bar when tightening the fixture group.

Move the number one rack in the fuel on direction and put the 9U7270 gauge block in position on the number one injector with 3.5 mm wide “finger” positioned between the injector rack head stop pin and the square shoulder on the injector body. Release the rack. The gage block is to be secured to the fixture group by the chain.

The detent should protrude 1.25 mm to 2.25 mm when the gage block and fixture is installed correctly. This will insure that the proper tension is held on the gage block while the injectors are synchronized.



SLIDE 83

Install the digital indicator

Zero injector

Adjust injector

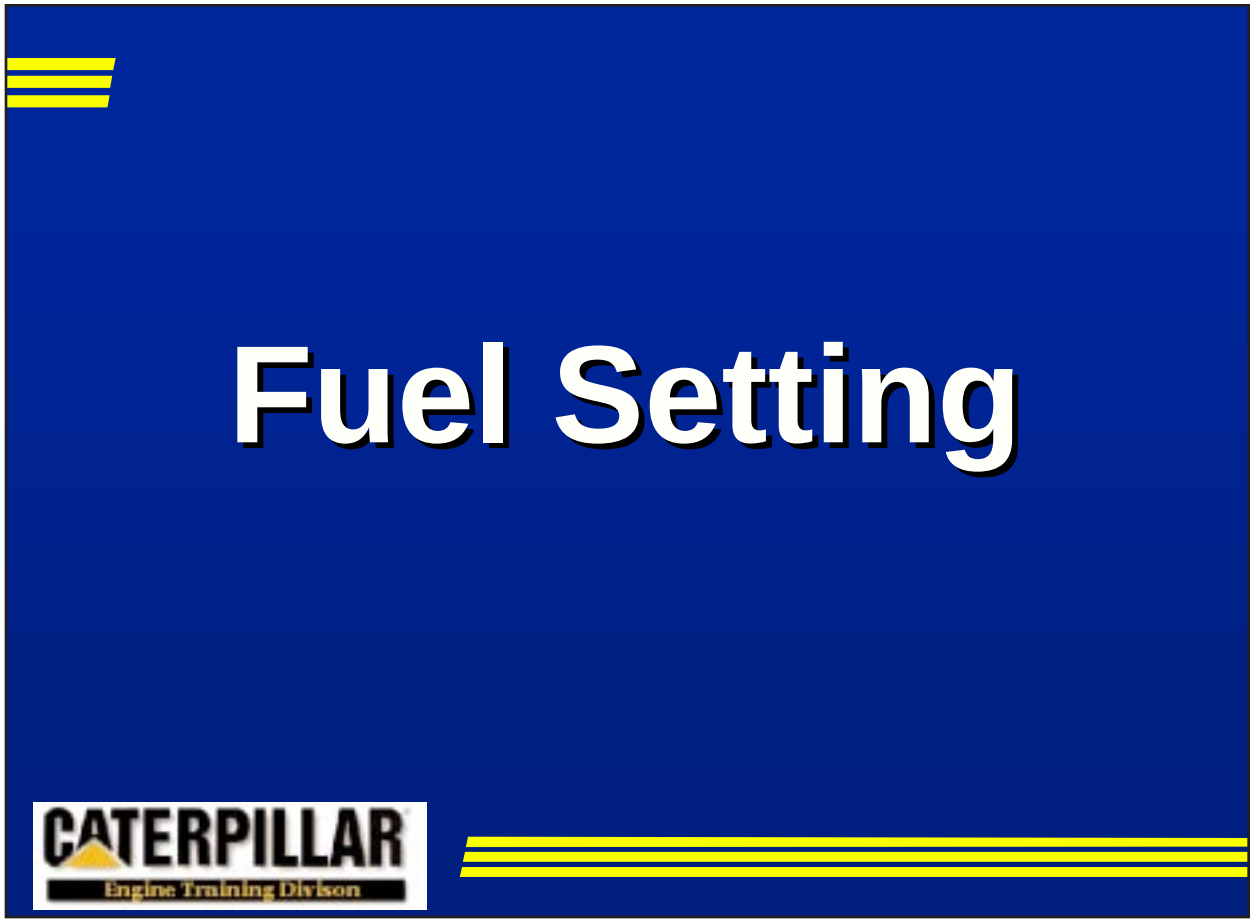
Install the 1U8869 digital indicator with contact point into the 9U7282 indicator fixture group. Remove bolt nearest to the injector to be checked and install indicator group where bolt was removed. Tighten the bolt and make sure ball tip on lever of indicator group makes contact with end face of the rack bar.

Turn the indicator on. Make sure the indicator is set to mm. Use the 128-8823 locking pliers to rotate the control assembly to shut- off position. Use the pliers to rotate the control assembly until the injector rack head stop pin contacts the shoulder on the injector body. This is the fuel shut-off position. While maintaining this position press the “zero-set” button on the dial indicator. This defines the zero-rack (shut-off) position. Repeat this sequence several times to obtain consistent results.

Push down and quickly and release head of injector being checked to make sure there is smooth movement of the injector rack. The digital

indicator should now read 3.50 ± 0.02 mm. If an adjustment is necessary, use the 1U6673 wrench and turn set screw until indicator reads 3.50 ± 0.02. Tighten the locknut while holding set screw in position.

The valve clearance and fuel timing should be checked after installing the rocker arm assembly.



SLIDE 84

Fuel setting

Fuel setting screw

Injectors should be synchronized

Fuel setting is the adjustment of the fuel setting screw to a specified position with reference to the number one rack. The fuel setting screw limits the power output of the engine by setting the maximum travel of number one injector and then hence all the injector racks to control maximum fuel flow. Before the fuel setting is checked, the injectors should be correctly synchronized, or a badly synchronized could cause binding of the rack actuation mechinism.

SLIDE 85

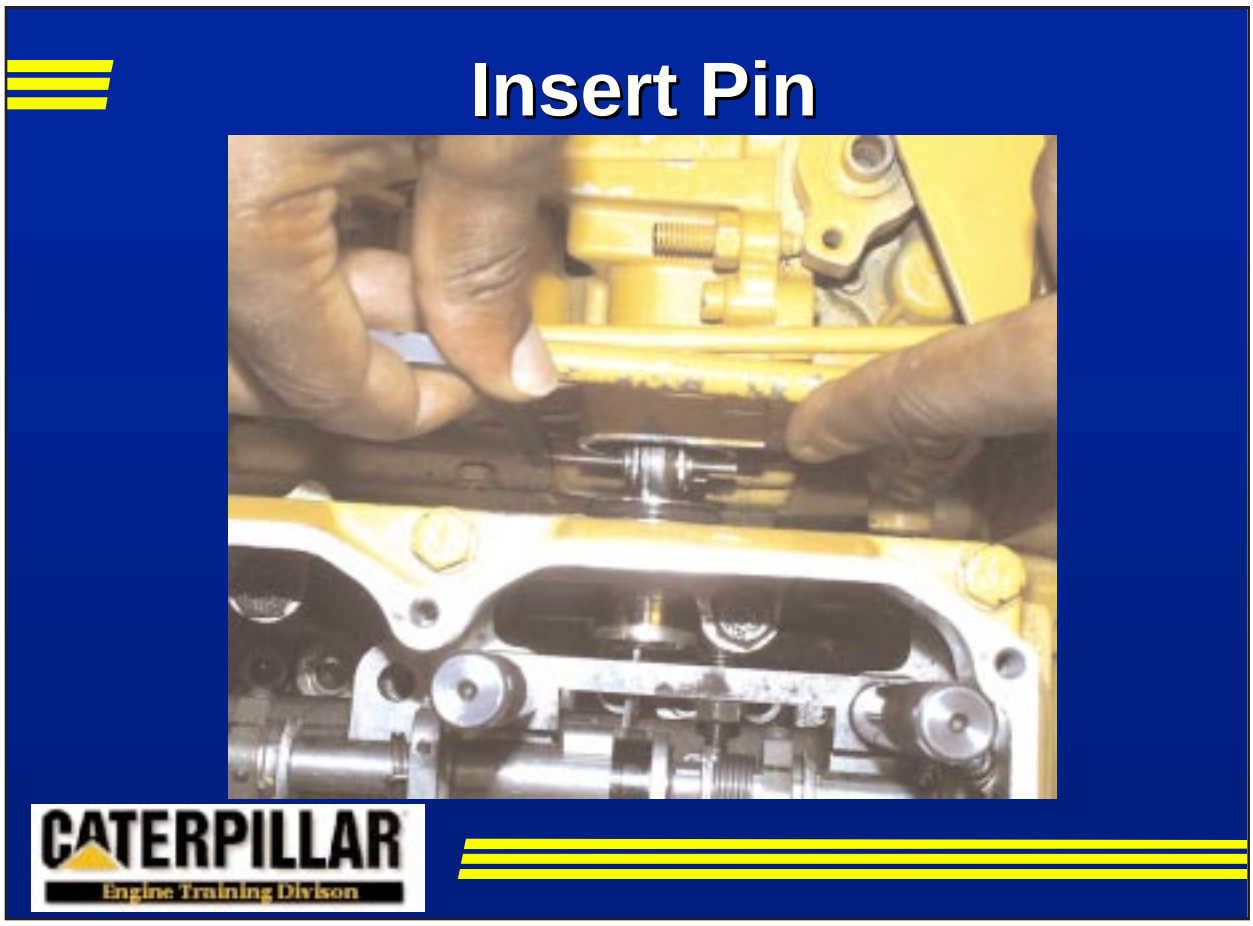
Fuel setting adjustment using the 128-8822 tool group

Remove sleeve

Fuel setting adjustment using the 128-8822 tool group.

To make the fuel setting adjustment using the 128-8822 tool group, remove the clip that keeps the sleeve in position between governor and inlet manifold. Using the 6V6006 pliers, slide the sleeve from governor toward the inlet manifold. Do not use hard jawed pliers or a screwdriver to move the sleeve. Damage may result to the sleeve which may damage the wiper seal in the inlet manifold when the sleeve is installed in the inlet manifold.

Later engines have a groove in the governor end of the sleeve that may be used to pry the sleeve out of the governor housing.

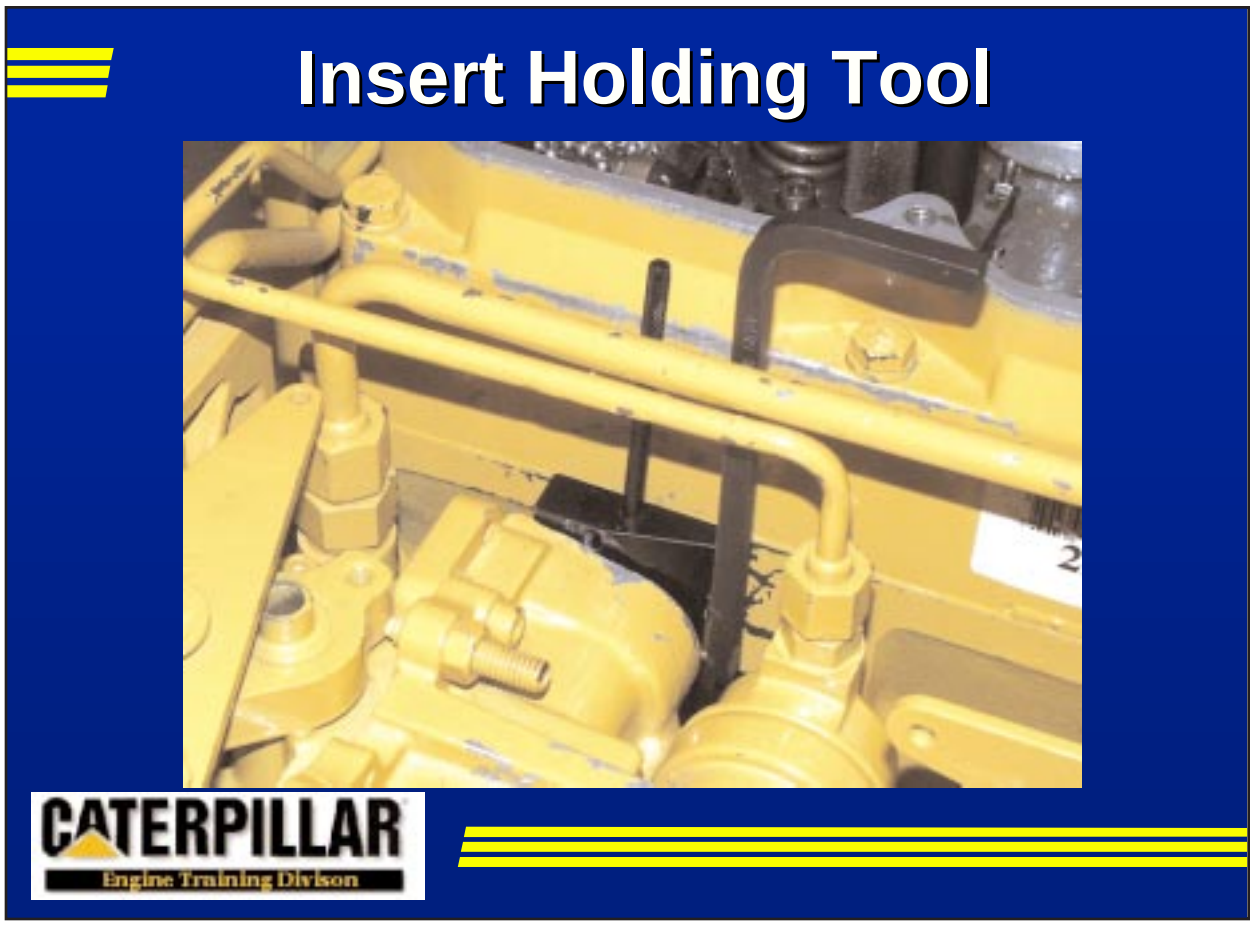


SLIDE 86

Install calibration pin

The 128-8822 tool group uses a tapered holding tool. It should be assembled to hold the insertion tool against the governor housing.

To position the governor linkage, install the 9U7271 offset calibration pin into link pin of the governor output shaft. When properly installed, equal lengths of small diameter on pin will extend from both ends of link pin.

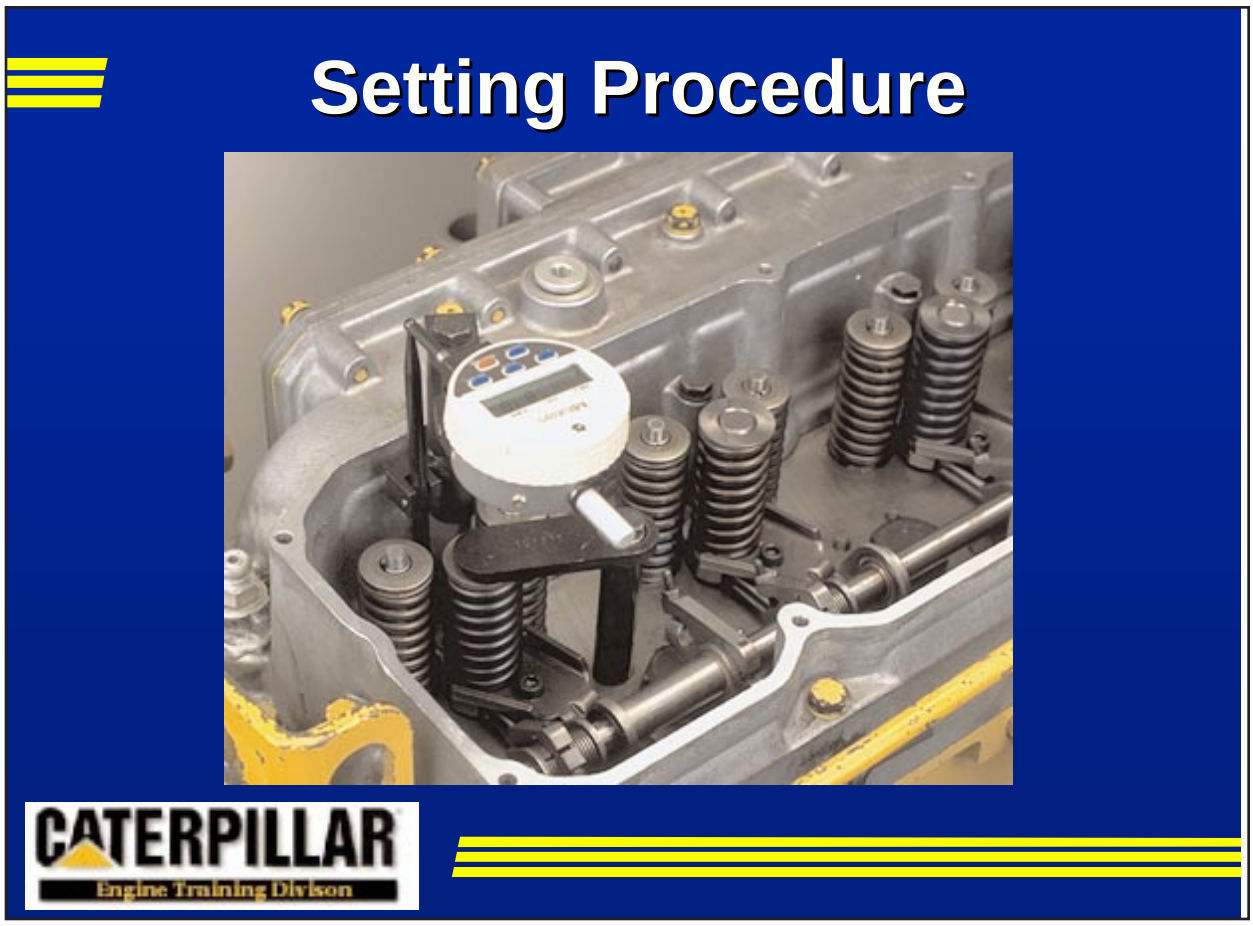


SLIDE 87

Install holding tool

Do not overtighten

Install the 9U7265 clamp assembly to retain offset calibration pin tightly against the governor housing calibration face. When inserting the tapered holding tool, use just enough force to hold the pin against the governor. Heavy force on the tapered holding tool could cause the pin to indent itself in the face of the governor housing. This is the fuel setting measurement position.



SLIDE 88

Install the digital position indicator

Zero the indicator

Check and adjust fuel setting

Install the 1U8869 digital position indicator into 9U7282 indicator fixture group. Tighten the nylon screw. Remove the bolt from inlet manifold near the number one injector and install the indicator fixture group. Be sure the ball on end of lever makes contact with end face of rack bar. Turn the indicator to ON. Be sure the indicator units are set to mm and ± travel direction is correct (plunger traveling out of indicator should read positive).

Push rack head of the number 1 injector, by hand, toward the injector until rack head stop pin touches square shoulder of injector body, and hold in this position. The number.1 injector is now at fuel shut-off. Press the “zero-set” button on the indicator to define zero rack at this position.

Repeat this process several times to ensure a consistent zero point has been established. Push down on the control lever and quickly release it. “Flip” the lever in this manner to make sure there is smooth movement

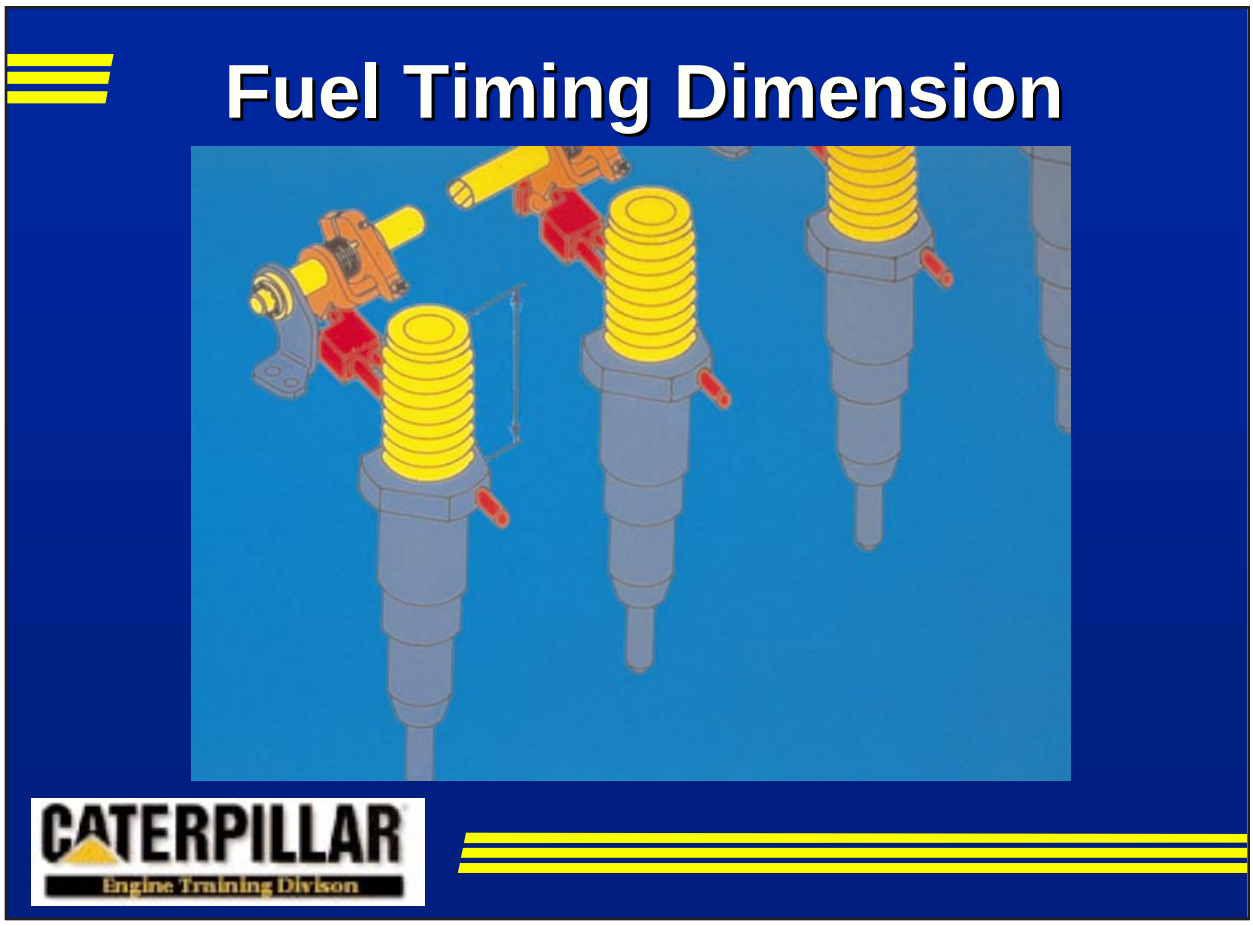
of the injector rack. The reading on the dial indicator is the engine's current fuel setting.

If an adjustment is necessary, use the 1U6673 wrench to loosen the locknut of fuel setting screw and adjust the indicator reading to the correct fuel setting. Turn the screw counterclockwise to increase the fuel setting or clockwise to decrease the fuel setting.

SLIDE 89

Fuel injection timing

Fuel injection timing is a standard that permits the setting of all unit injectors to the same vertical position on the camshaft base circle so that the beginning of injection takes place in each combustion chamber a specific number of crankshaft degrees before top center. Fuel timing is specified as a dimension in millimeters.



SLIDE 90

Distance from follower to injector body

Injector scroll

Adjusting sequence

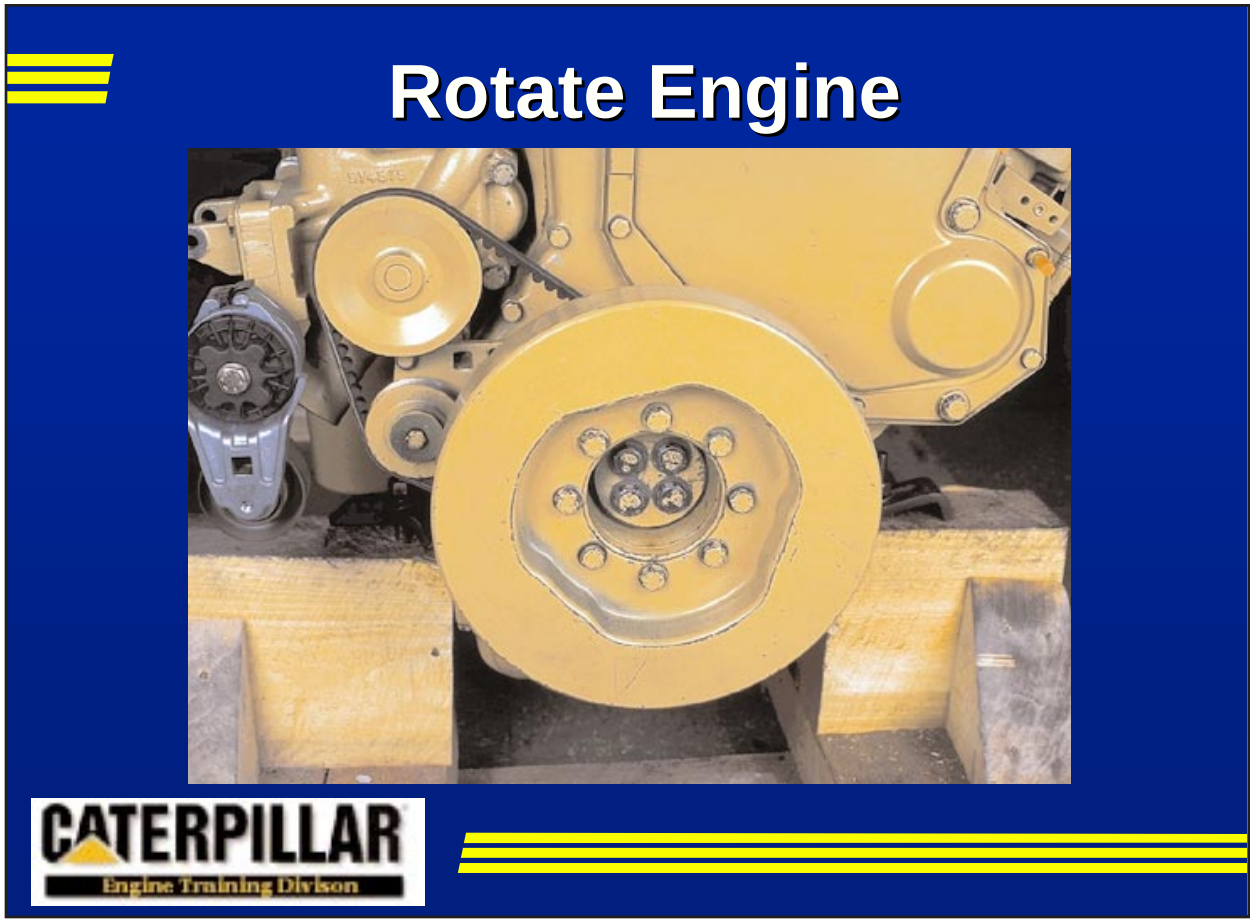
The dial indicator measures the distance from the top of the injector follower to the injector body surface. This measurement gives the relationship of the scroll on the plunger with the ports in the barrel.

Fuel timing can be checked or adjusted during the two-crankshaft position sequence for valve clearance setting, or turning the crankshaft in the direction of normal rotation until the injector is at maximum height and the push rod is at its lowest point (the lifter assembly is at its lowest point on the base circle of the cam).

Check and adjust injectors 3 and 4 on a 4 cylinder engine, with number 1 piston on top center compression stroke. Check and adjust injectors 1 and 2 on a 4 cylinder engine, with number 1 piston on top center exhaust stroke.

Check and adjust injectors 3, 5, and 6 on a 6 cylinder engine, with number 1 piston on top center compression stroke. Check and adjust injectors 1, 2, and 4 on a 6 cylinder engine, with number 1 piston on top

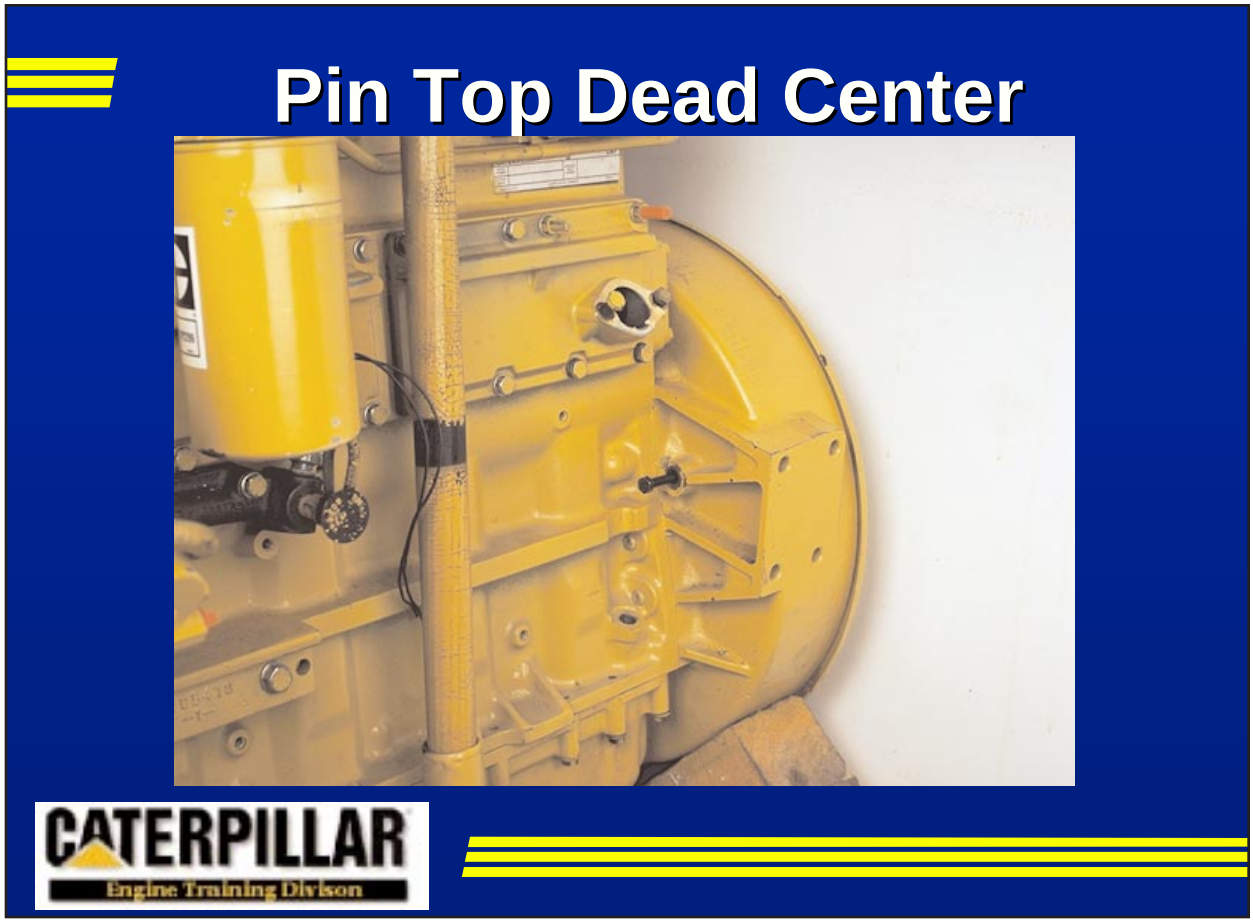
center exhaust stroke.



SLIDE 91

Rotate crankshaft using the larger bolts

Rotate the engine to top dead center of cylinder number one. Always turn the engine crankshaft with the four large bolts on the front of the crankshaft. Do not use the eight small bolts on the front of the crankshaft pulley. If the rocker arm assemblies are removed and installed prior to setting the fuel timing dimension, rotate the crankshaft two complete revolutions to allow the rocker arms to properly seat on the injectors.



SLIDE 92

Rotate in the direction of normal rotation

Install timing bolt

Confirm the position of #1 cylinder

Rotate crankshaft in the direction of normal rotation, until bolt goes into front of flywheel housing and screws into flywheel. This position is top dead center. Check the position on the intake and exhaust valves to confirm that the number one cylinder is on the compression or exhaust stroke.

SLIDE 93

Programming the digital indicator

Before a check or an adjustment of the fuel timing dimension can be made, the digital indicator must be programmed to a preset value of 62.00 mm. This is the dimension of the Timing Gauge Block (9U7269).

(A) Turn the indicator ON by pushing the “ON/OFF” button.

(B) Push the “in/mm” button so the display shows mm.

A negative sign(-) should be in the display window under REV. If the space is blank, push the “+/-” button so the display shows (-). When this is done, plunger movement into the indicator will show on the display as negative movement, and plunger movement out of the indicator as positive movement.

(D) Push and hold the “preset” button down until there is a flashing “P” in the upper right corner of the display, and then release.

(E) Push and hold the “preset” button down until the “P” stops flashing and a flashing indicator bar is seen in the lower left corner of the

display, and then release. Momentarily pushing the “preset” button will cause a minus sign (-) to appear or disappear above the flashing indicator. Use the “preset” button to make this position blank.

(F) Push and hold the “preset” button down until flashing indicator begins to flash under the first number position (fourth position to the left of the decimal), then release. Momentarily pushing the “preset” button will cause the display number in that position to change. Use the preset button to make the position show zero.

(G) Use the “preset” button to move the flashing indicator and change the display numbers until the display shows 0062.00 mm.

(H) Push and hold the “preset” button until the flashing “P” is shown in the upper right corner of the display, and then release. Momentarily push the “preset” button so the flashing “P’ and the zeros to the left of 62.00 mm disappear.

(I) Turn the indicator OFF. The indicator will retain the preset number in memory (only one preset number can be retained). To recall the preset number, repeat steps A-D. Then Momentarily push the “preset” button so the flashing “P” and the zeros to the left of 62.00mm disappear. Install the 85mm long Contact Point (9U7274) on the digital indicator stem.

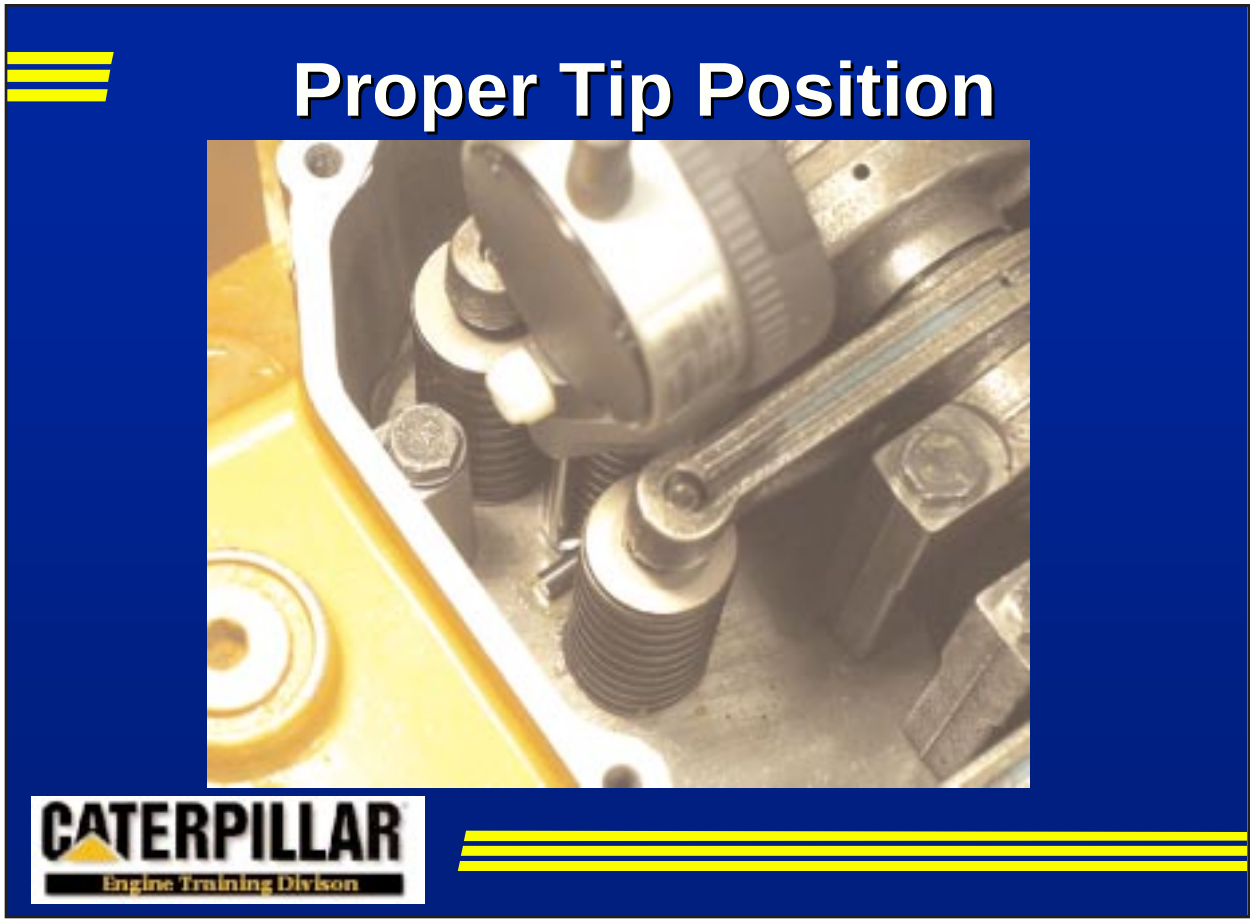
Put Digital Indicator in the 9U7308 Indicator Fixture Group until it stops. Tighten nylon holding screw. Make sure the magnetic bottom of indicator fixture group and top and shoulder of Timing Gauge Block (9U7269) are clean Place indicator and base assembly on the timing gauge block. Once the base attaches, let the plunger out. Repeat steps A-D and momentarily push the “preset” button until 62.00 mm appears.

SLIDE 94

Adjusting the timing dimension

When the digital indicator and magnetic base are positioned on the injector, the indicator will display the current fuel timing dimension. Refer to the engine information plate or TMI for the correct fuel timing dimension. If the indicator displays the correct dimension or within the ± 0.20mm tolerance, no adjustments are necessary. If indicator does not show the correct timing dimension, turn the adjusting screw until the digital indicator displays the correct fuel timing dimension. Tighten the locknut to 25 ±7 N•m (18.0 ± 5.0 Ib ft) and check adjustment again. Repeat procedure if necessary until the adjustment is correct.

Check and adjust all of the injectors that can be done for the current engine position. Rotate the engine 360 degrees and repeat the process for the remaining injectors.



SLIDE 95

Install the magnetic base on the injector

Remove digital indicator and magnetic base from the gauge block and carefully position it on top of injector tappet for the injector to be checked. Make sure indicator contact point is on the shoulder of the injector and indicator plunger moves freely. Assure that when the tip is raised, the measured amount reduces.

Small Engine Fuel Systems

Lesson Plan 10 - Unit Injector Adjustment Lab

Objectives:

- In the lab, the student will demonstrate proper removal and assembly of a unit injector into the cylinder head.
- In the lab, the student will demonstrate the ability to set injector synchronization to specifications using the provided literature and tooling.
- In the lab, the student will demonstrate the ability to time injectors to the proper height using the provided literature and tooling.
- In the lab, the student will demonstrate the ability to make power settings on the engine using the provided literature and tooling.

Literature Needed:

Systems Operation Testing and Adjusting 3114, 3116 & 3126	SENR3583
Using the 128-8822 Tool Group on 3114, 3116, & 3126 Engines	NEHS0610

Hardware Needed:

1.1 or 1.2 Engine

128-8822 Tool Group

Metric Hand Tools

Time Required:

3 Hours

Tasks Required by Instructor to Meet Objectives:

1. The instructor is to change the injector timing, synchronization and power setting for the training engine prior to the class.
2. Have the students remove injector #1 and #2. Replace them switching positions of the injectors.
3. Using the listed injector tool group, have the students synchronize all injectors. Assure that each student has opportunity to synchronize at least one injector using the tool group.
4. Time all injectors. Assure that each student has opportunity to time at least one

injector. If time is available, have the students check and set valve lash.

5. Adjust the power setting. This may be repeated until all students have had an opportunity to adjust the fuel setting.

Small Engine Fuel Systems

Lesson Plan 11 - 1.1 and 1.2 Governor Disassembly and Assembly

Objectives:

- The student will be able to disassemble, assemble and make appropriate internal adjustments of the 1.1 and 1.2 Liter Engine Governor given proper tooling and literature.

Literature Needed:

Service Manual, 3114, 3116, 3126 Engine Governor SENR6454

Hardware Needed:

1.1 or 1.2 Liter Engine Governor

128-8822 1.1 Liter Engine Injector Tool Group

1U7315 1.1 Liter Engine Governor Tool Group

Metric Hand Tools

Time Required:

2 Hours

Tasks Required by Instructor to Meet Objectives:

1. Remove the governor from the engine if required.
2. Using the disassembly procedure in the service manual, disassemble the governor halves. After the governor has bee separated, have the students miss-adjust anything that can be later adjusted.
3. Have the student look up the Governor Performance Data from TMI.
4. Using the assembly procedure in the service manual and the Governor Performance Data from TMI, adjust and assemble, as required, the governor.

Small Engine Fuel Systems

Lesson Plan 12 - Quiz 2

Objectives:

- The student will take a quiz to review and test the previous day's material. A minimum of 70% accuracy is considered acceptable.

Literature Needed:

Quiz 2 Copy

Hardware Needed:

None

Time Required:

0.5 Hour

Tasks Required by Instructor to Meet Objectives:

1. Ask student for questions regarding ;material covered the previous day.
2. Answer all questions using reference material. Be sure the students follow along in their reference material while the question is answered.
3. Administer the Quiz 2
4. Review the Quiz 2, again using reference material to answer questions.

Small Engine Fuel Systems

Lesson Plan 12 - Quiz 2

Select the best answer - If the answer is false on a true/fales, correct the question to make it true

1. The Type II governor used on a 3114 engine:
   A. Is the same as the Type I governor except it has a Type Code “B”on the information plate
   B. Has two governor flyweights and uses a servo to control rack movement
   C. Has four governor flywieghts to control rack movement
   D. Has no torque cam adjustment

2. The 3114 engine has a centrifugal timing advance unit built ino the cam gear and has a maximum advance of 6 degrees.
   A. True
   B. False

3. The fuel setting on 3116 engines can be made with the governor attached to the engine.
   A. True
   B. False

4. When adjusting a 1.1 or 1.2 liter engine governor on the governor test bench, the governor output at peak torque is checked by:
   A. Increasing the bench speed by 100 rpm and lowering bnack to the adjustment specification speed
   B. Performing function check 2
   C. The output at peak torque can not be tested on a 1.1 or 1.2 engine governor
   D. Performing function check 3

5. When setting the dial indicator on the governor test bench, the reference setting dimension for a governor with a load stop dimension less than 9.00 mm is:

   A. 0.00 mm

   B. 9.00 mm

   C. 8.00 mm

   D. The dimension that is found in the Governor Performance data in TMI

6. The torque cam adjustment dimension is found:

   A. Testing and Adjusting

   B. Governor Performance Data

   C. Disassembly and Assembly

   D. Engine Information Plate

7. The set point for a 3116 truck engine is 20 rpm above rated speed.

   A. True

   B. False

8. A 3116 engine shows a timing dimension of 63.56 on the engine plate. When using the 128-8822 Injector Tool Group, the setting on the dial indicator when on the fixture would be:

   A. 62.00 mm

   B. 1.56 mm

   C. 63.56 mm

   D. -1.56 mm

9. The throttle stop on a 1.1 liter governor works exactly like a high idle screw on other engines.

   A. True

   B. False

10. The throttle lever orientation should be checked on Type 1, 2 and 3 governors before making any other governor adjustments.

    A. True

    B. False

11. If an engine was producing 597 pound feet of torque at 2200 rpm, how much horsepower would it be producing?

12. How much horsepower would you expect from a 210 hp @ 2200 3126E truck engine if it was using 39 API @ 55 degrees F fuel, 67 degrees F fuel temperature, 101 degrees air temperature and 28.56”Hg barometric pressure? Would this custormer probably complain of a power problem? Why?

Small Engine Fuel Systems

Lesson Plan 12 - Quiz 2

Select the best answer - If the answer is false on a true/fales, correct the question to make it true

1. The Type II governor used on a 3114 engine: C
   A. Is the same as the Type I governor except it has a Type Code “B”on the information plate
   B. Has two governor flyweights and uses a servo to control rack movement
   C. Has four governor flywieghts to control rack movement
   D. Has no torque cam adjustment

2. The 3114 engine has a centrifugal timing advance unit built ino the cam gear and has a maximum advance of 6 degrees. B - MUI can’t have a TAU
   A. True
   B. False

3. The fuel setting on 3116 engines can be made with the governor attached to the engine. A
   A. True
   B. False

4. When adjusting a 1.1 or 1.2 liter engine governor on the governor test bench, the governor output at peak torque is checked by: D
   A. Increasing the bench speed by 100 rpm and lowering bnack to the adjustment specification speed
   B. Performing function check 2
   C. The output at peak torque can not be tested on a 1.1 or 1.2 engine governor
   D. Performing function check 3

5. When setting the dial indicator on the governor test bench, the reference setting dimension for a governor with a load stop dimension less than 9.00 mm is: C

   A. 0.00 mm

   B. 9.00 mm

   C. 8.00 mm

   D. The dimension that is found in the Governor Performance data in TMI

6. The torque cam adjustment dimension is found: B

   A. Testing and Adjusting

   B. Governor Performance Data

   C. Disassembly and Assembly

   D. Engine Information Plate

7. The set point for a 3116 truck engine is 20 rpm above rated speed. B - There is no set poing on a 3116 governor, settings are made on a bench

   A. True

   B. False

8. A 3116 engine shows a timing dimension of 63.56 on the engine plate. When using the 128-8822 Injector Tool Group, the setting on the dial indicator when on the fixture would be: A

   A. 62.00 mm

   B. 1.56 mm

   C. 63.56 mm

   D. -1.56 mm

9. The throttle stop on a 1.1 liter governor works exactly like a high idle screw on other engines. B - This setting also can change fuel rate

   A. True

   B. False

10. The throttle lever orientation should be checked on Type 1, 2 and 3 governors before making any other governor adjustments. B -These governors do not have type II throttles which are press on

    A. True

    B. False

11. If an engine was producing 597 pound feet of torque at 2200 rpm, how much horsepower would it be producing?

    250 = 597 X 2200 / 5252

12. How much horsepower would you expect from a 210 hp @ 2200 3126E truck engine if it was using 39 API @ 55 degrees F fuel, 67 degrees F fuel temperature, 101 degrees air temperature and 28.56”Hg barometric pressure? Would this custormer probably complain of a power problem? Why?

    39.4 API @ 60 degrees F

    208.5 = 21- / (1.019 X 0.982 X 0.994 X 1.013)

    No, less than 15 hp loss

Small Engine Fuel Systems

Lesson Plan 13 - 1.1 and 1.2 Governor Test Stand Lab

Objectives:

- The student will be able to demonstrate the ability to properly set a 1.1 and 1.2 Liter Engine governor using the 1U7326 Governor Calibration Bench and proper literature.

Literature Needed:

Service Manual, 3114, 3116, and 3126 Engine Governors SENR6454

Hardware Needed:

1.1 or 1.2 Liter Engine Governor

1U7326 Governor Calibration Bench

1U9786 Calibration Pin

1U6673 FRC Adjustment Wrench

1U9893 Solenoid Spanner Wrench

6V6106 Dial Indicator

1U8815 Contact Point

15 psi Air Supply

Time Required:

2.25 Hours

Tasks Required by Instructor to Meet Objectives

1. Using the 1U7326 Governor Calibration Bench, cover the steps involved in setting a 1.1/1.2 governor
2. Have the students look up the Governor Performance data in TMI.
3. Have the students conduct all required tests and settings on a governor.
4. Answer any questions the students have about the checking or setting procedure.

Small Engine Fuel Systems

Lesson Plan 14 - 1.1 & 1.2 HEUI Fuel System Injector Sleeve Lab

Objectives:

- The student will be able to remove and install an injector sleeve from a 3126 abd 3126B/E cylinder heads.

Literature Needed:

Using the 127-3458 SleeveReplacement Tool Group SEHS9120

Hardware Needed:

3116 or 3126 and 3126B/E Engines

Hand Tools

127-3458 Sleeve Replacement Tool Group

Time Required:

1.75 Hour

Tasks Required by Instructor to Meet Objectives:

1. Using the Special Instruction, remove an injector sleeve from the engine.
2. Using the Special Instruction, reinstall the injector sleeve and follow the proper procedure reaming the sleeve seat for a new injector installation.
3. Repeat the process in the form of a demonstration for the 3126B/E sleeve.

Small Engine Fuel Systems

Lesson Plan 15 - Introduction to 1.1 and 1.2 HEUI Fuel Systems

Objectives:

- The student will be able to explain the operation, disassembly, assembly, setting procedure and testing of the 1.1 and 1.2 liter HEUI fuel system with 70% accuracy on a written test.

Literature Needed:

1.1 and 1.2 HEUI Fuel System Slide Script Copy

Hardware Needed:

Slide Projector

Screen

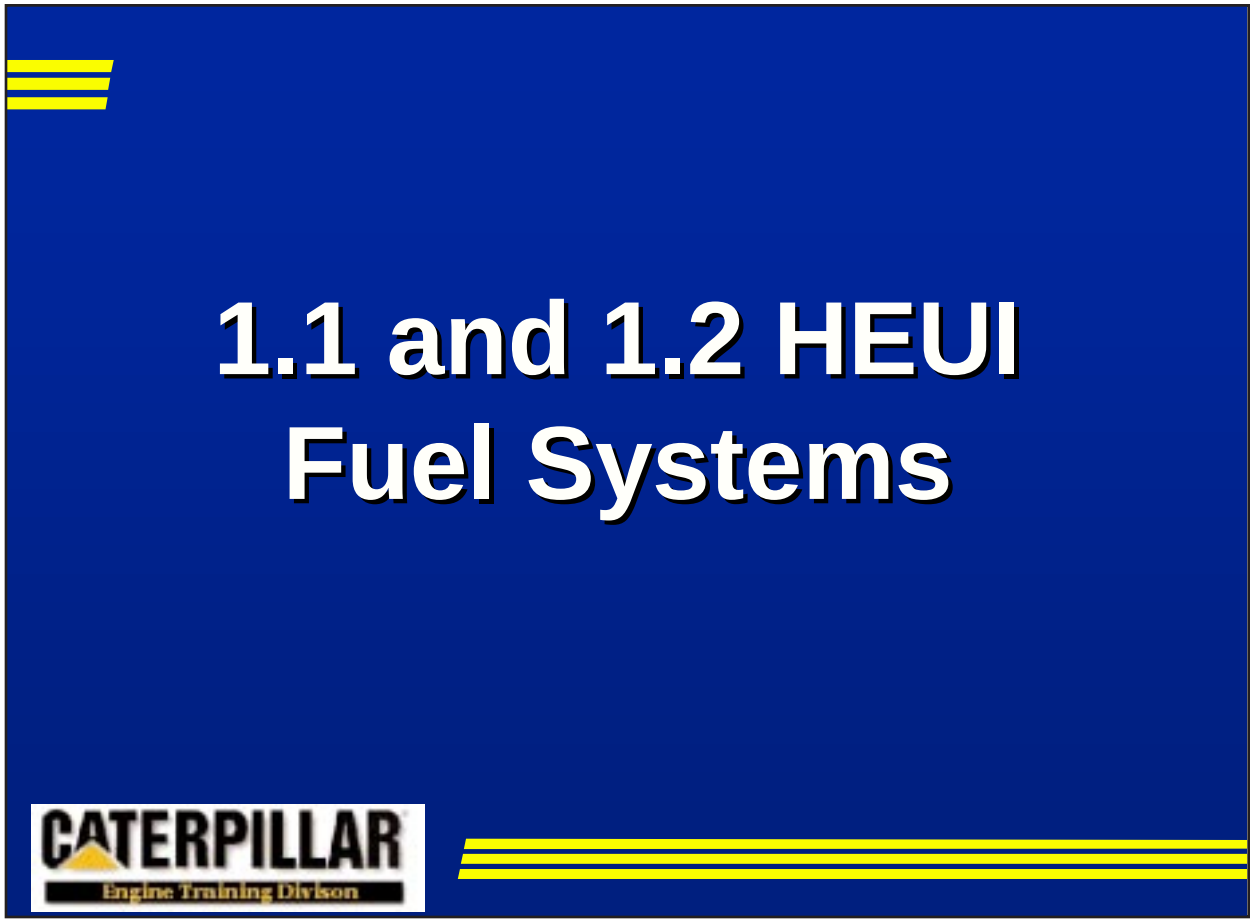
1.1 and 1.2 HEUI Fuel System Slides

Time Required:

2 Hours

Tasks Required by Instructor to Meet Objectives:

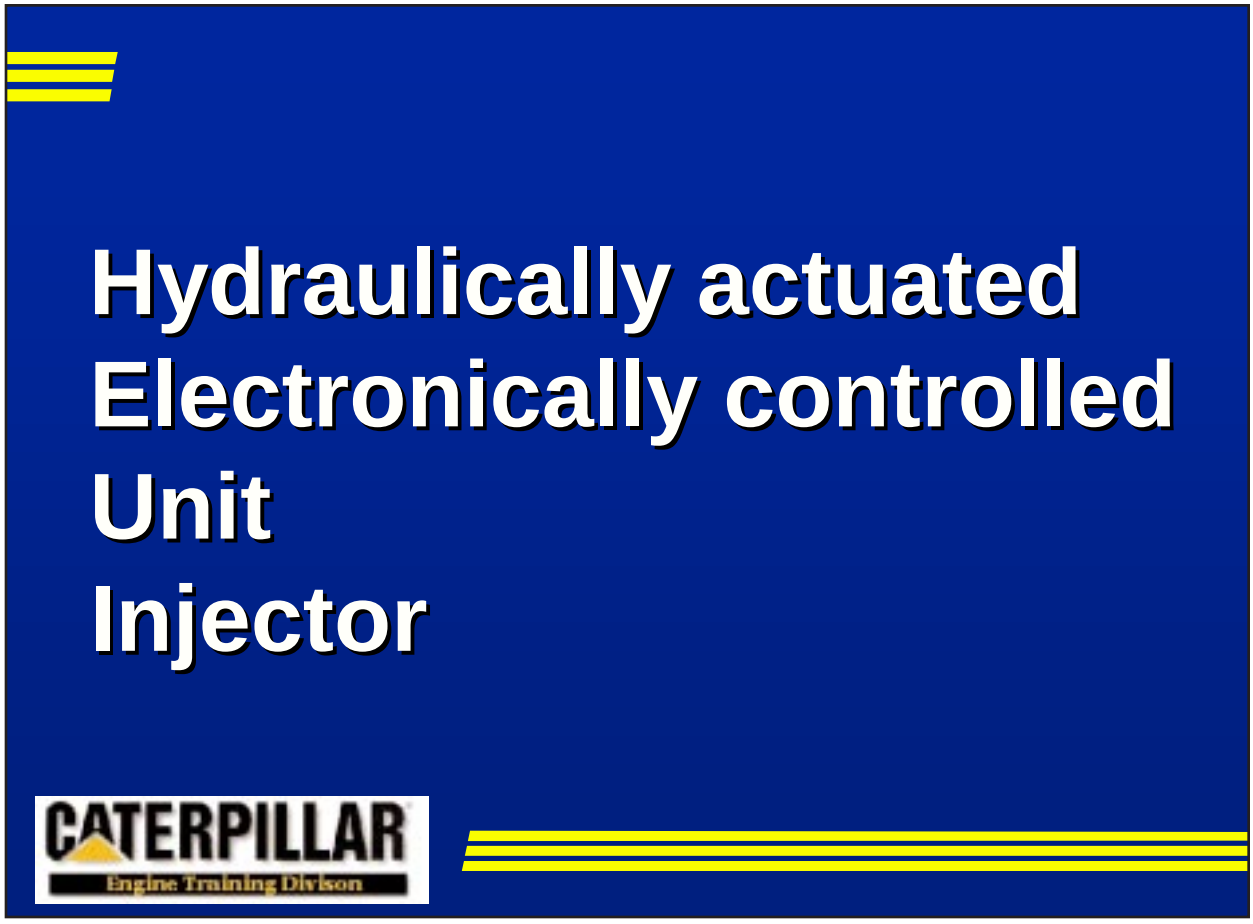
1. Review the slides and emphasize the following points:
   A. Benefits of the HEUI fuel system
   B. Five major components of the HEUI fuel system
   C. Fuel flow through the fuel system
   D. Oil flow through the engine
   E. Oil flow through the high pressure system
   F. Location of components
   G. Removal and installation of an injector
   H. Removal and installation of an injector sleeve
   I. Operation of the HEUI injector
   J. Operation of the injection actuation pressure control valve



SLIDE 96

HEUI fuel system

This presentation introduces the 3116/ 3126 HEUI fuel system. It will cover the operation of the fuel system and the mechanical components of the engine. We will touch on the HEUI electronics, but not cover them in great detail. We will start with the 3116/3126 system and then move to the 3126B/E system



SLIDE 97

H-E-U-I

Governor

Hydraulically actuated

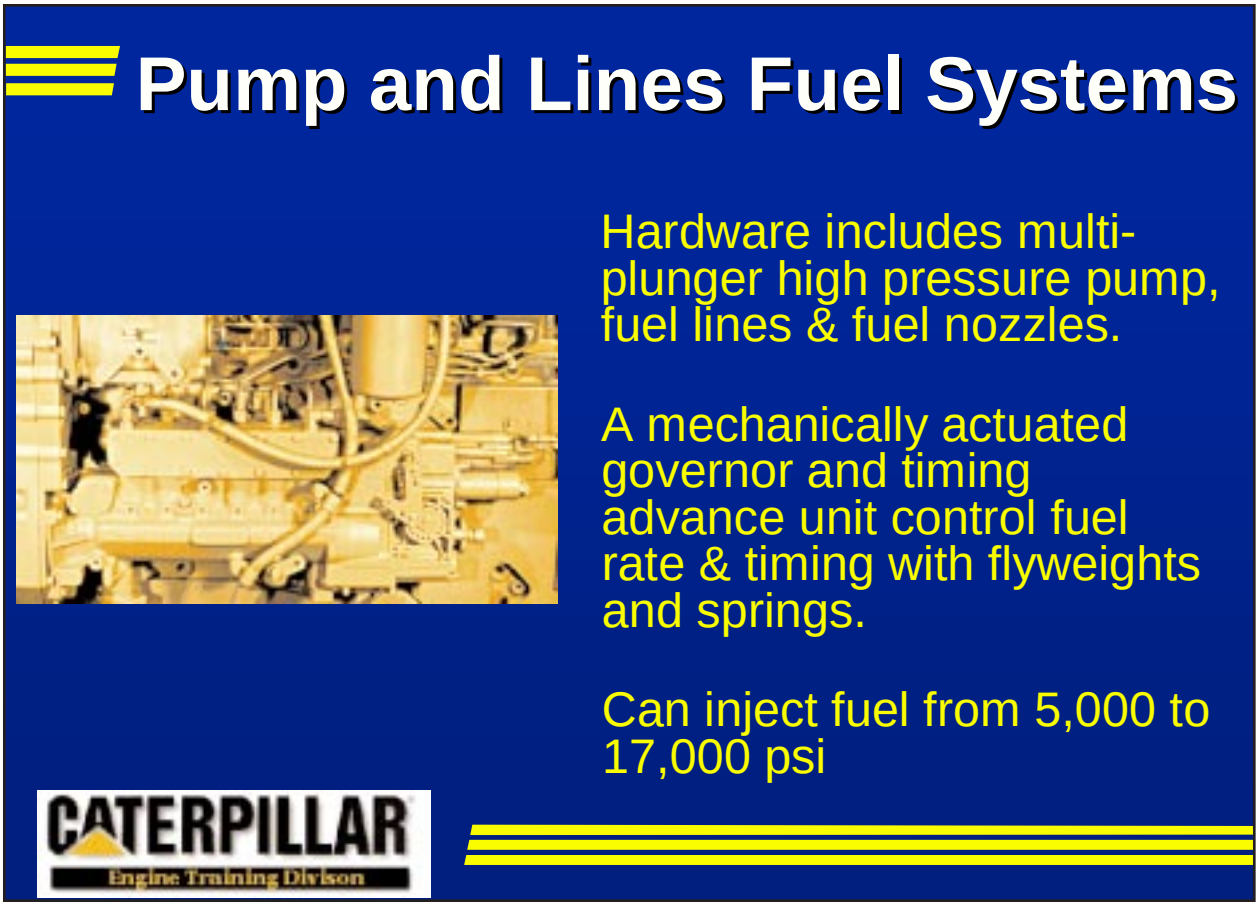
HEUI stands for Hydraulically actuated, Electronically controlled, Unit Injector. It differs from the 3116 and 3126 MUI system in two ways.

First, the MUI system uses a mechanical governor to control the rack and fuel rate, the HEUI fuel system is controlled by an electronic governor (ECM). All of the functions performed by the mechanical governor are now done by an ECM (electronic control module).

Also, the MUI fuel system uses a camshaft, pushrod and rocker arm assembly to actuate the injector or inject the fuel into the cylinders. The HEUI fuel system uses hydraulic oil pressure to move the plunger.

SLIDE 98

Over the years fuel system technology has dramatically evolved. Today we use HEUI fuel systems, but there have been several other fuel systems we have used coming to this point. In the following few slides, we will look at these various systems with both their good points and some of their limitations.


Pump and Lines Fuel Systems
Hardware includes multi-plunger high pressure pump, fuel lines & fuel nozzles.
A mechanically actuated governor and timing advance unit control fuel rate & timing with flyweights and springs.
Can inject fuel from 5,000 to 17,000 psi
CATERPILLAR
Engine Training Division

SLIDE 99

The most common fuel system used on heavy duty diesel engines is the scroll type pump and lines direct injection system. Direct injection means the nozzle sprays fuel directly into the combustion chamber rather than through a prechamber. Direct injection systems offer improved performance, emissions and economy, but requires higher injection pressures and better control of fuel atomization. This system has three main components:

— Multiple plunger pump

— High pressure fuel lines

— Fuel injection nozzles

The pump housing contains a cam actuated plunger and barrel assembly for each engine cylinder. The plunger and barrel pressurizes and meters the precise amount of fuel needed for each cylinder. The high pressure fuel pulse is mechanically timed so that it travels through the high

pressure fuel line and opens the injection nozzle at the proper time. The injector nozzle serves as a high pressure check valve which atomizes the high pressure fuel for combustion and prevents residual fuel from leaking into the cylinder.

Pump & Lines Fuel Systems

Limiting Factors

High pressure fuel lines.

Fuel rate & timing control.

Fuel injection pressure

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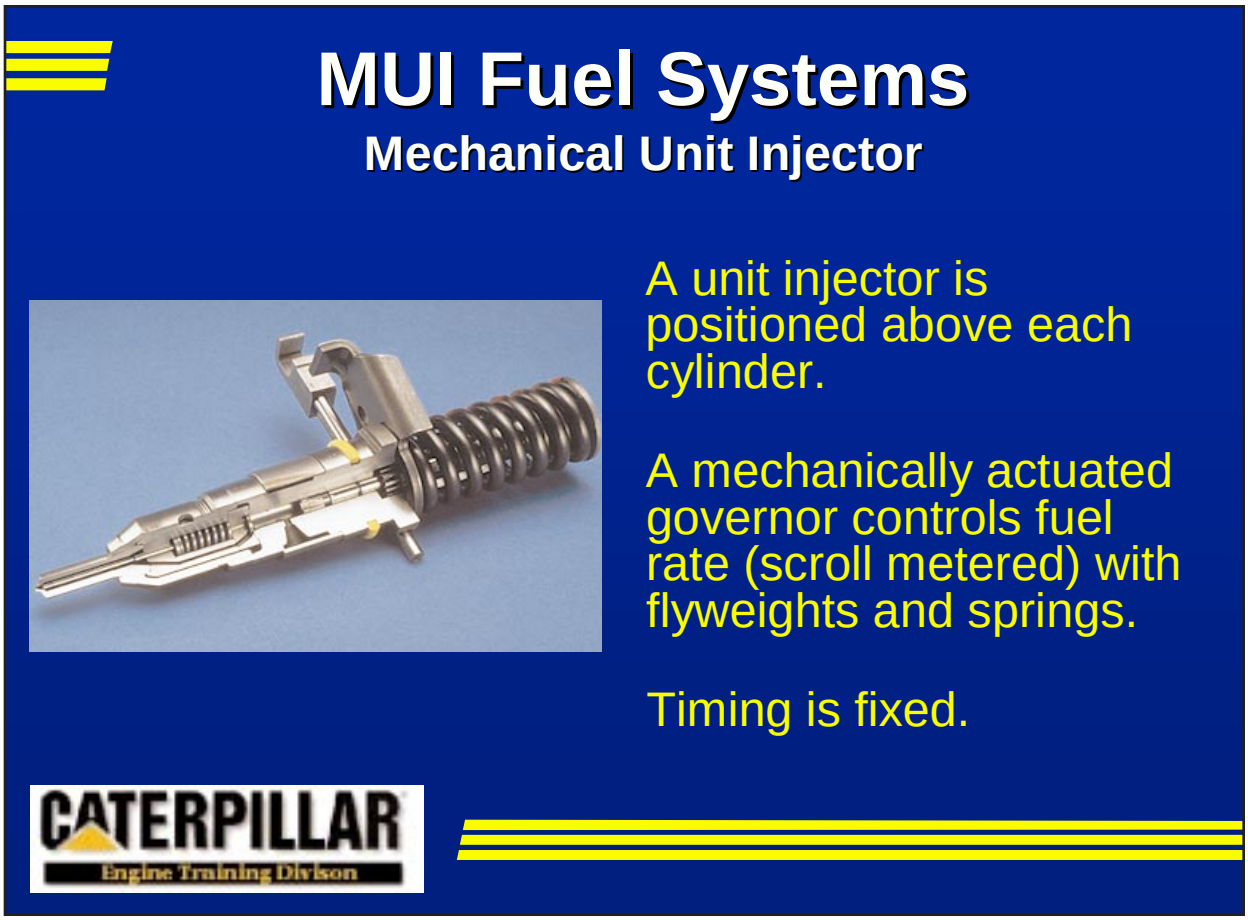
SLIDE 100

Pump and lines systems are very reliable and durable, but are structurally limited to about 18,000 psi maximum injection pressure. They also have limited injection timing and injection rate capabilities. Current engine emissions and performance requirements, at times, demand injection pressures in excess of 20,000 psi and greater timing flexibility to met today’s emissions standards.


MUI Fuel Systems
Mechanical Unit Injector
A unit injector is positioned above each cylinder.
A mechanically actuated governor controls fuel rate (scroll metered) with flyweights and springs.
Timing is fixed.
CATERPILLAR
Engine Training Division

SLIDE 101

The mechanical unit injector system was at one time used only on very large bore engines to eliminate the need for long high pressure fuel lines and the related problems inherent with controlling pressures in these fuel lines. The mechanical unit injector (MUI) contains a nozzle assembly which performs the same function as a fuel injection nozzle. The MUI also contains a plunger and barrel to pressurize and meter the fuel for that cylinder. The plunger is actuated by a mechanical drive train. This drive train requires an additional cam lobe, lifter, push rod and rocker arm for each cylinder.

Fuel is metered by a scroll type plunger in the unit injector, which is controlled by mechanical linkage to the governor.

MUI Fuel Systems

Mechanical Unit Injector

Advantages:

High pressure fuel lines are eliminated.

Can inject at up to 23,000 psi

Limiting Factors:

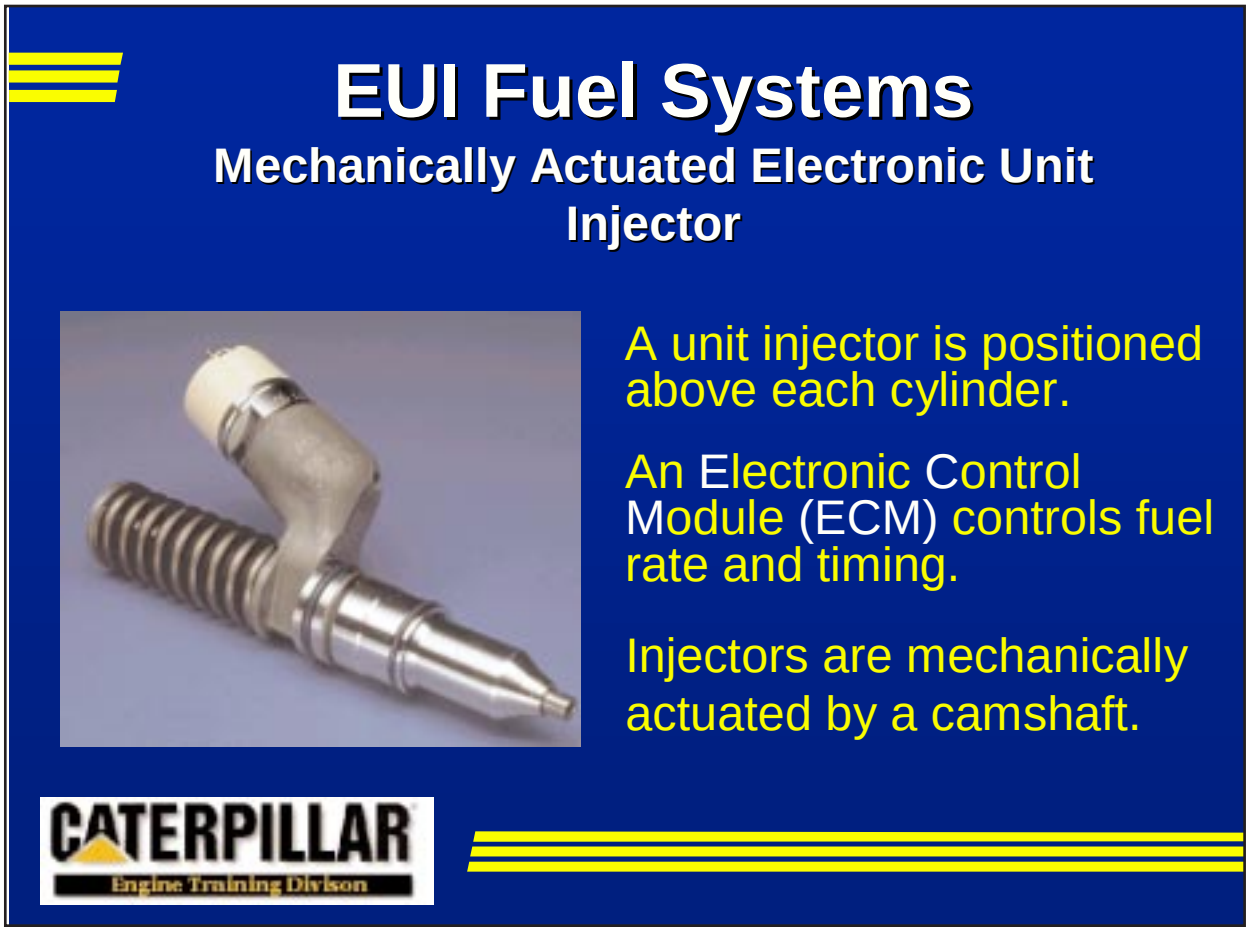
No timing advance

Mechanical actuation & governor control

CATERPILLAR
Engine Training Division

SLIDE 102

The major advantage of this system is the elimination of the high pressure fuel lines. However, the ability to precisely meter the fuel for varying conditions is limited by the capabilities of the mechanical governor. Since the MUI is activated by the engine camshaft, timing advance is also not available.


EUI Fuel Systems
Mechanically Actuated Electronic Unit Injector
A unit injector is positioned above each cylinder.
An Electronic Control Module (ECM) controls fuel rate and timing.
Injectors are mechanically actuated by a camshaft.
CATERPILLAR
Engine Training Division

SLIDE 103

The Electronically Controlled Mechanically Actuated Unit Injector (EUI) has some additional advantages. While this system still requires a mechanical valve train to actuate the plunger, the fuel is metered electronically by means of a solenoid operated poppet valve.

PRE-INJECTION

With the early models, the plunger moves down during the injection stroke, it closes off the fill port and pushes fuel out of the plunger cavity. Fuel flows past the nozzle check, around the poppet valve and out the spill port to drain. In later models, the fill port was eliminated and fill and spill go through the same port.

INJECTION

When the Solenoid is energized, it closes the poppet valve and blocks the path to drain. The downward travel of the plunger causes pressure to build and immediately open the nozzle. Injection continues as long

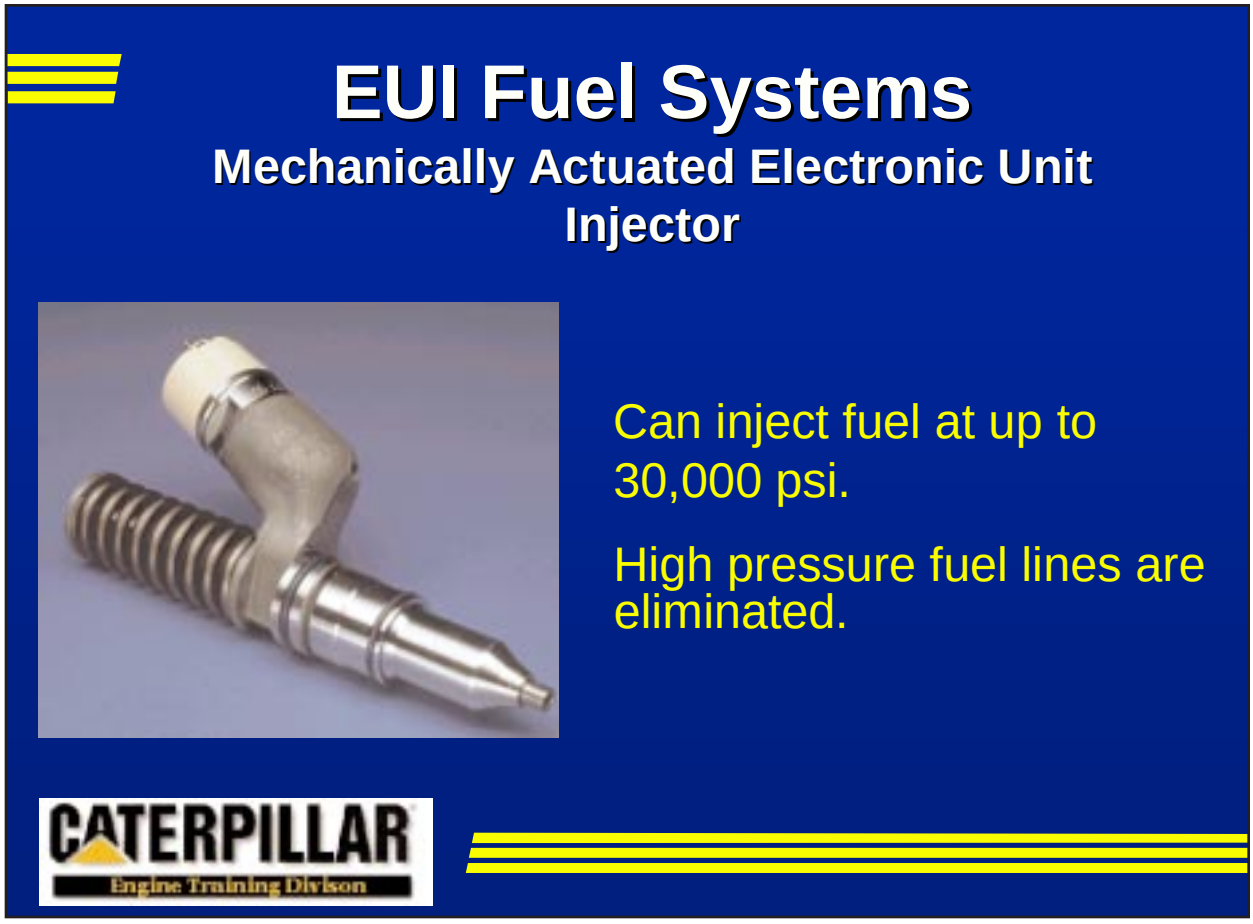
as the solenoid is energized and the plunger continues its downward stroke.

END OF INJECTION

Injection stops when the solenoid is de-energized and the poppet valve opens. Fuel now flows around the poppet to drain. The rapid drop in pressure allows the nozzle check to close, ending injection.

PLUNGER FILL

As the plunger travels upward, it uncovers the fill or the fill/spill port and draws fuel into the plunger cavity.


EUI Fuel Systems
Mechanically Actuated Electronic Unit Injector
Can inject fuel at up to 30,000 psi.
High pressure fuel lines are eliminated.
CATERPILLAR
Engine Training Division

SLIDE 104

There are three major advantages to this system.

First, the start and end of injection can be controlled to occur at any time during the downward stroke of the plunger. An electronic control module (ECM) actuates the solenoid operated spill valve.

Second, this system has higher injection pressure capability than any other system. The 3406E/C-15/C-16 injectors produces up to 30,000 psi injection pressure for maximum fuel atomization.

Finally, the electronic control can sense road speed, load and several other inputs to provide better part throttle performance, improved fuel economy and lower emissions.

EUI Fuel Systems

Mechanically Actuated Electronic Unit Injector

System Limiting Factor:

Injection pressure is dependent on engine speed (rpm).

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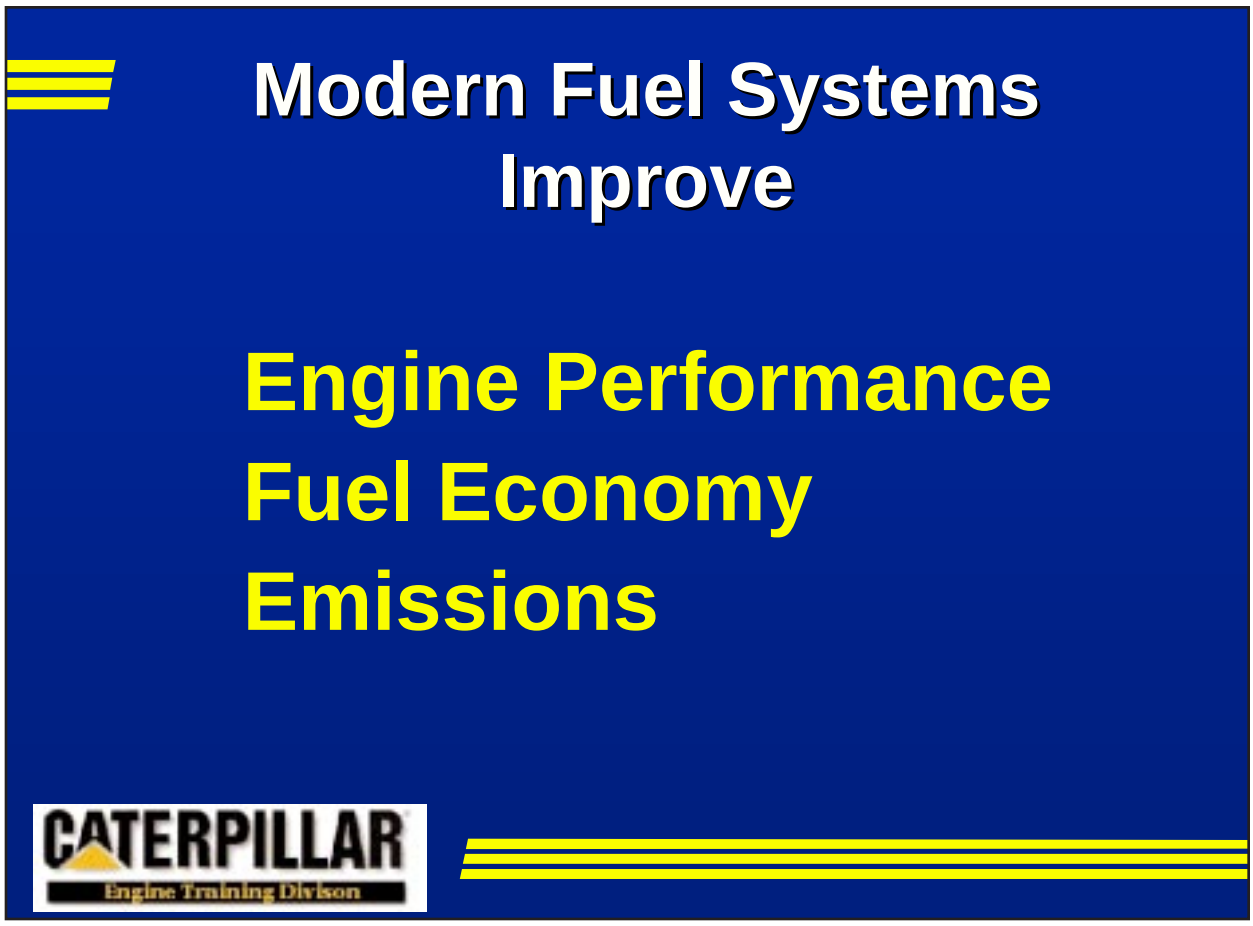
Engine Training Division

SLIDE 105

As with the multiple plunger system, however, injection pressure is determined by the speed of the plunger pushing the fuel through a fixed orifice (the nozzle). There is a direct relationship between engine speed, plunger speed and the resultant injection pressure.

It is desirable to achieve maximum injection pressure at peak torque engine speed. However, since peak torque speed is less than rated speed, injection pressure is also less. For the 2000's, we need a fuel system that will produce high injection pressures at any engine load or speed.

Demands for greater fuel economy and lower exhaust emissions in the 2000's require vastly improved fuel system performance. The HEUI meets these requirements.



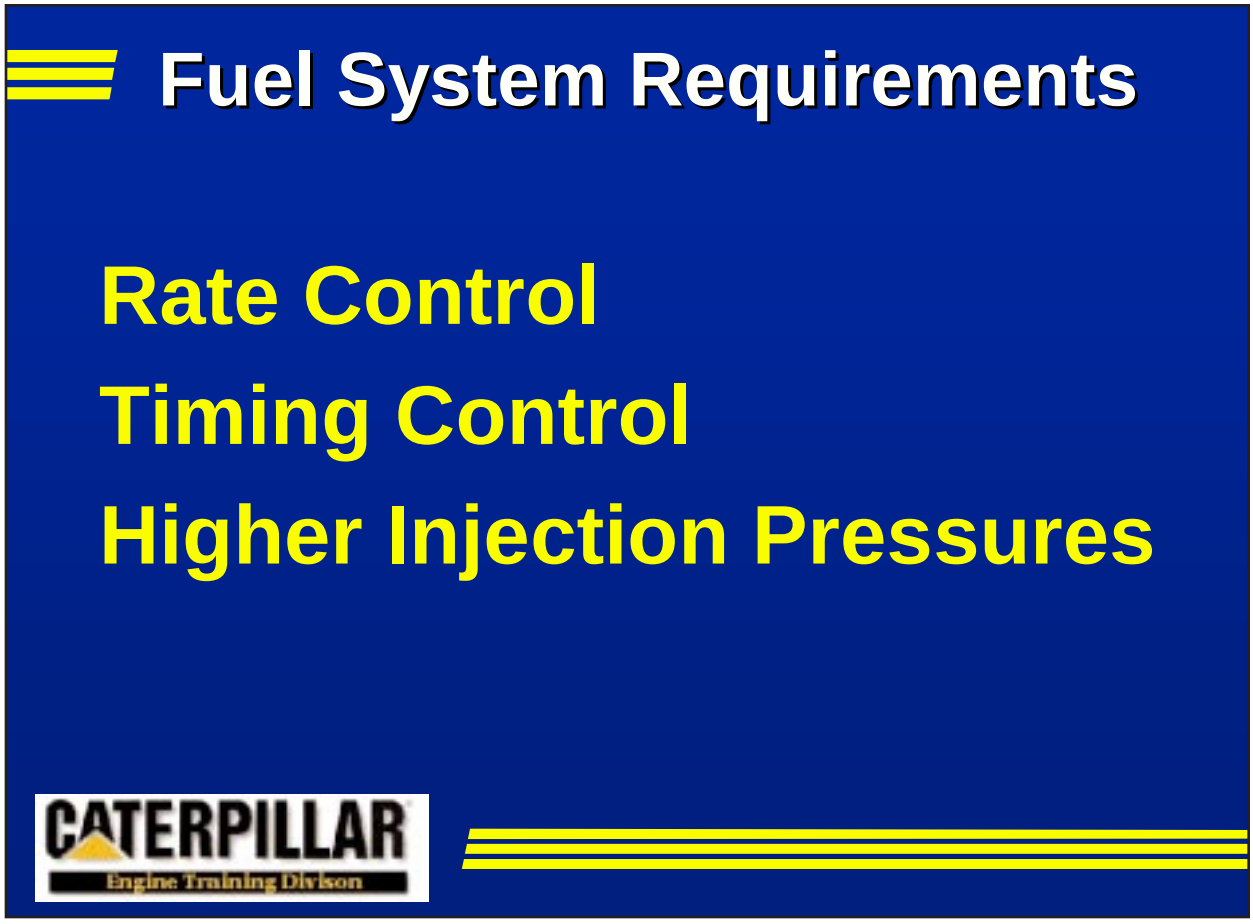
SLIDE 106

Performance

Fuel economy

Emissions

Customer demand for increased performance and better fuel economy along with changing emission regulations have been a significant factor in the evolution of fuel system technology. Other types of fuel systems, although very reliable, have their limitations and can no longer meet these demands.



SLIDE 107

Rate control

Timing control

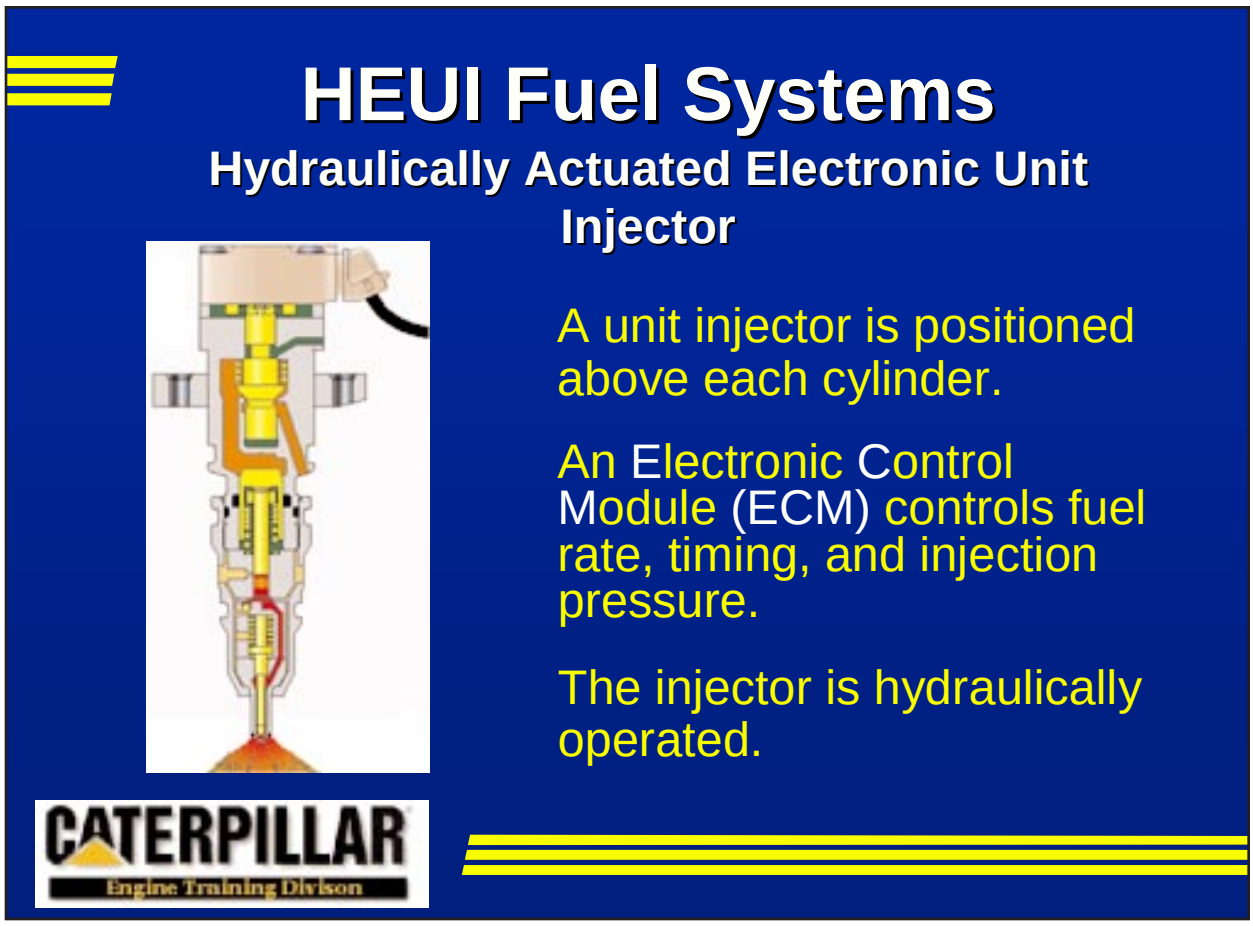
Higher injection pressures

The HEUI fuel system is capable of meeting the demands for performance, fuel economy and emissions by better control of the injection process. It is able to meet these demands by controlling injection rate, injection timing and injection pressures.

The rate of injection can be controlled to meet any engine condition. Because the unit injector is hydraulically actuated rather than mechanically actuated, its rate of injection does not depend on engine speed as it does with a pump and lines group or other injectors.

Both the start and end of injection is electronically controlled. Unlike the electronic unit injector, the HEUI plunger does not move until the solenoid is energized. This means that plunger movement is not limited to the speed or duration of a cam lobe.

An intensifier piston in the HEUI injector multiplies hydraulic force on the plunger. By varying hydraulic input pressure, injection pressure can be controlled in a range from 5,000 to 23,000 psi.


HEUI Fuel Systems
Hydraulically Actuated Electronic Unit Injector
A unit injector is positioned above each cylinder.
An Electronic Control Module (ECM) controls fuel rate, timing, and injection pressure.
The injector is hydraulically operated.
CATERPILLAR
Engine Training Division

SLIDE 108

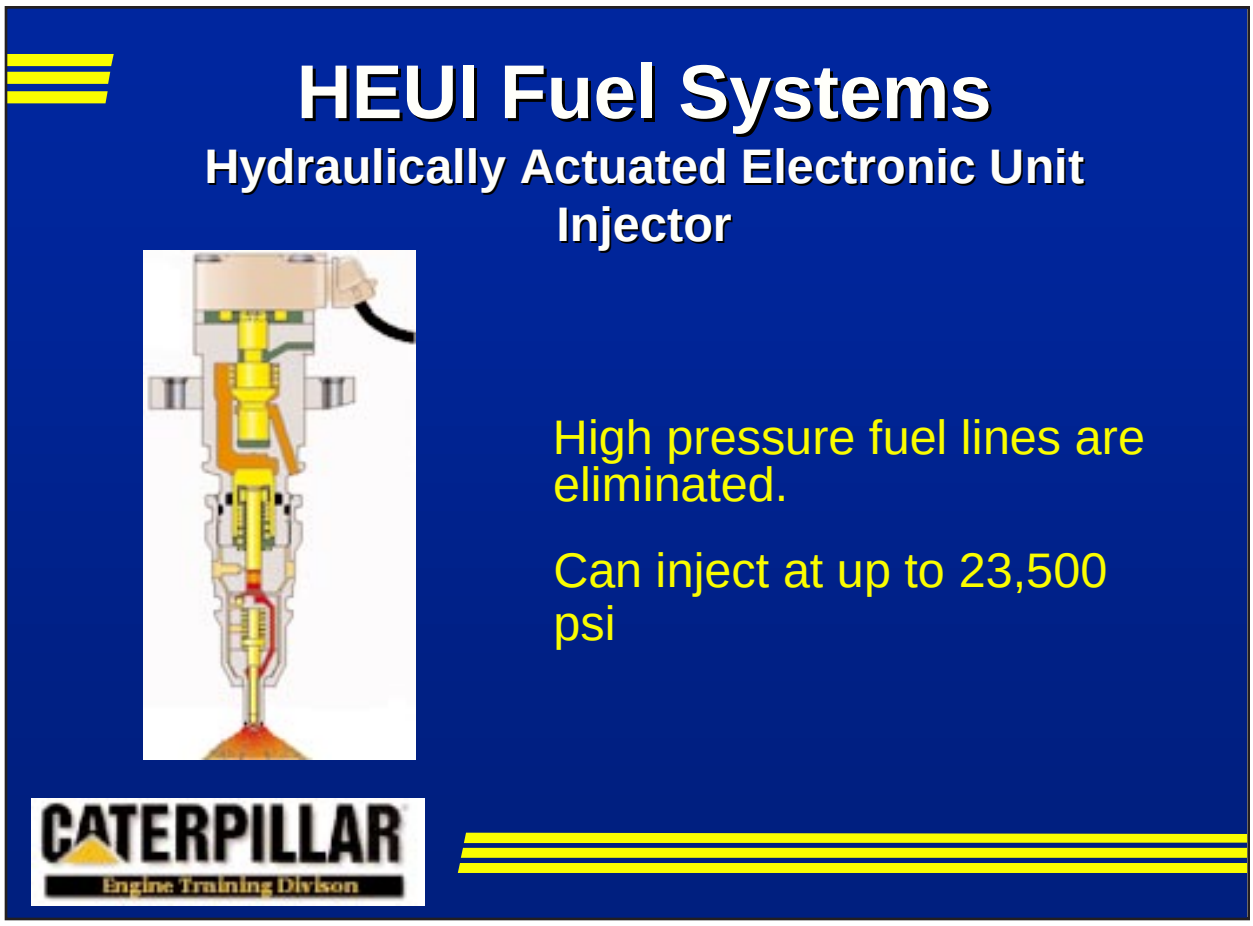
Single injector per cylinder

ECM controls

- Fuel Rate
- Timing
- Injection Pressure

Hydraulically Operated

The HEUI system has a single injector positioned above each of the cylinders. Each injector is controlled by the ECM for duration (fuel rate), timing and injection pressure. Each injector is electronically controlled and hydraulically operated.


HEUI Fuel Systems
Hydraulically Actuated Electronic Unit Injector
High pressure fuel lines are eliminated.
Can inject at up to 23,500 psi
CATERPILLAR
Engine Training Division

SLIDE 109

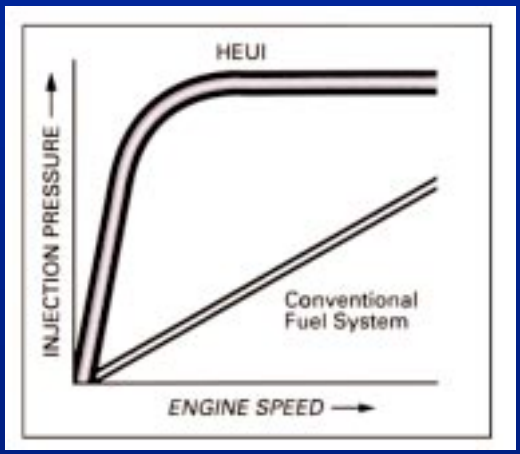
No High Pressure Fuel Lines

HEUI systems eliminate high pressure fuel lines. The system can achieve as high as 23,500 psi injection pressure.

23,500 psi Injection

HEUI Fuel Systems

Hydraulically Actuated Electronic Unit Injector



Injection pressure is infinitely controlled between maximum and minimum pressure limits, regardless of engine speed.

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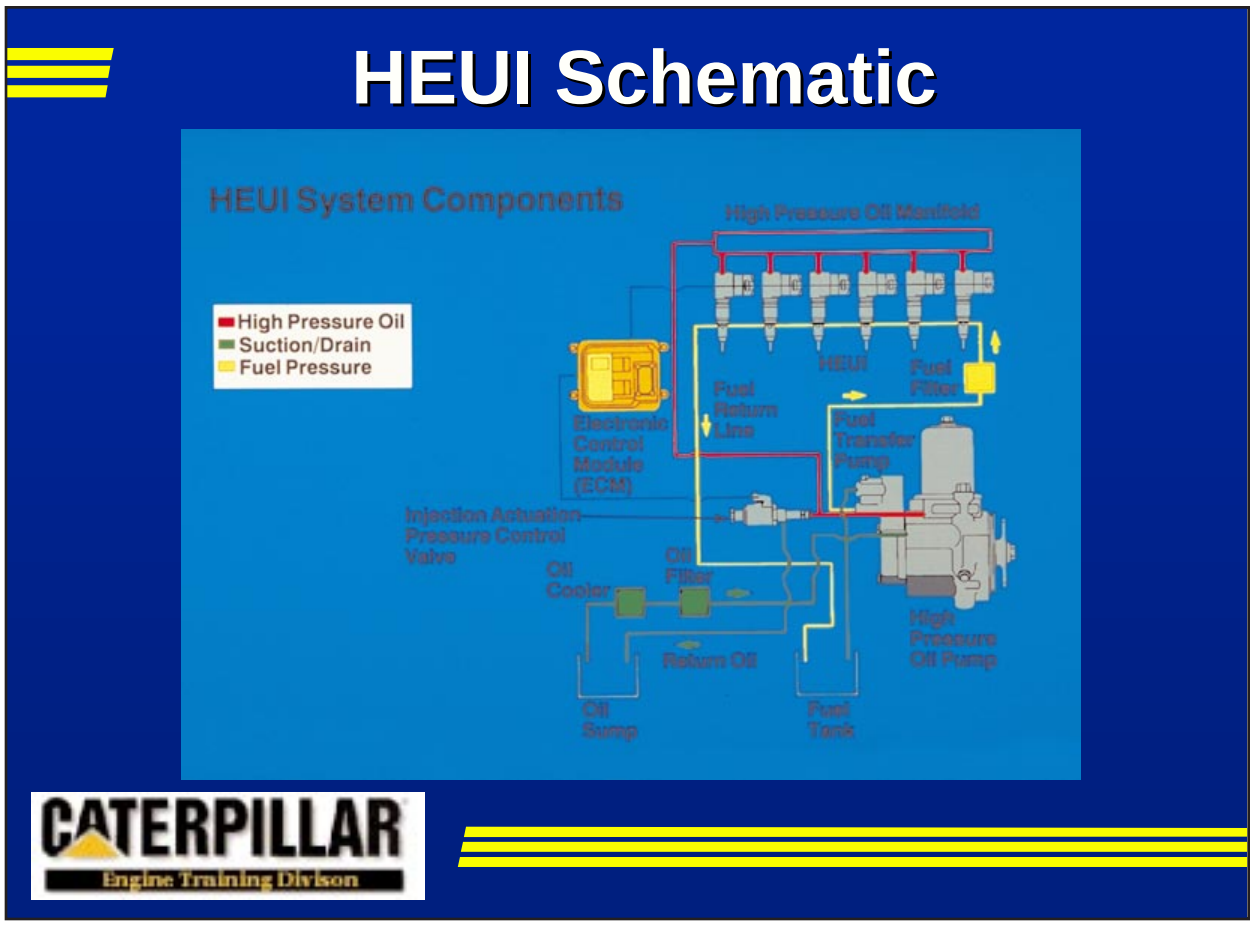
SLIDE 110

Peak Injection Pressures at any Speed

With any system other than HEUI, the peak injection pressure is dependant on engine speed. The slower the engine speed, the less peak injection pressure is available. With HEUI peak pressure can be obtained at about any engine speed, even low idle.



SLIDE 111

HEUI components

Now let's look at the basic components of the HEUI system.

The HEUI fuel system consists of five major components. They are: an electronic control module (ECM) and sensors, a high pressure oil pump, the oil manifold and oil lines, the fuel transfer pump and fuel lines, the injection actuation pressure control valve (IAPCV) and the HEUI Injectors.

ECM

The ECM is a programmable on-board computer which controls the operation of the entire fuel system as well as other engine functions. Because the ECM has many more operational inputs than a mechanical governor, it can determine optimum fuel rate, injection timing and injection pressure for almost any condition. Electronic controls such as this are absolutely essential in meeting new standards of exhaust emissions and noise.

Solenoid drivers in the ECM send a precisely controlled current pulse to the injector solenoid which energizes the solenoid. The magnetic field

created by the solenoid lifts the poppet valve off its seat which starts the injection cycle. The timing duration and current level of this pulse are controlled by logic circuits in the ECM. Fuel rate is a function of pulse duration and injection actuation pressure.

Hydraulic oil pump

The hydraulic supply pump is a fixed displacement axial piston pump. During normal engine operation, pump output pressure ranges from 5 MPa (725 psi) to 23 MPa (3335 psi). Output pressure is controlled by the Injection Actuation Pressure Control Valve (IAPCV) which dumps excess pressure and flow back to the return circuit. Pressures for specific engine conditions are determined by the ECM. During cranking, pump pressure is about 5 MPa (725 psi). This was raised to 735 psi on later engines and then raised to 870 psi for the 3126B/E.

Fuel transfer pump

The fuel transfer pump is a cam actuated single piston pump which is mounted on the rear of the high pressure oil pump. Fuel system pressure is maintained between 58-76 psi during normal operating conditions under load.

IAPCV

The IAPCV is an electrically operated dump valve which closely controls pump output pressure by dumping excess pressure and flow to the return circuit. A variable signal voltage from the ECM to the IACPV determines pump output pressure. Pump pressure can be maintained anywhere between 725 psi and 3335 psi during normal engine operation. Pressure while cranking a cold engine (below 30 degrees) may be higher than the normal 725 psi. The reason for this higher pressure during cold cranking is because cold oil is thicker and components in the injector move slower. The higher pressure helps the injector to fire faster until the viscosity of the oil is reduced. Due to the oil shearing action of internal engine components, such as rings and bearings, oil viscosity will drop by over 50% in the first two minutes after start-up.

Injector

The injector uses the hydraulic energy of the high pressure oil to cause injection. The pressure of the incoming oil controls the speed of the intensifier piston and plunger movement, and therefore, the rate of injection and injection pressure. The amount of fuel injected is determined by the duration of the pulse from the ECM and how long it keeps the solenoid energized. As long as the solenoid is energized and the poppet valve is off its seat, oil continues to push down the intensifier and plunger until the intensifier hits the bottom of its bore.

SLIDE 112

Left side of engine

ECM

Hydraulic oil pump

IAPCV

Fuel transfer pump

Oil manifold

Fuel flow

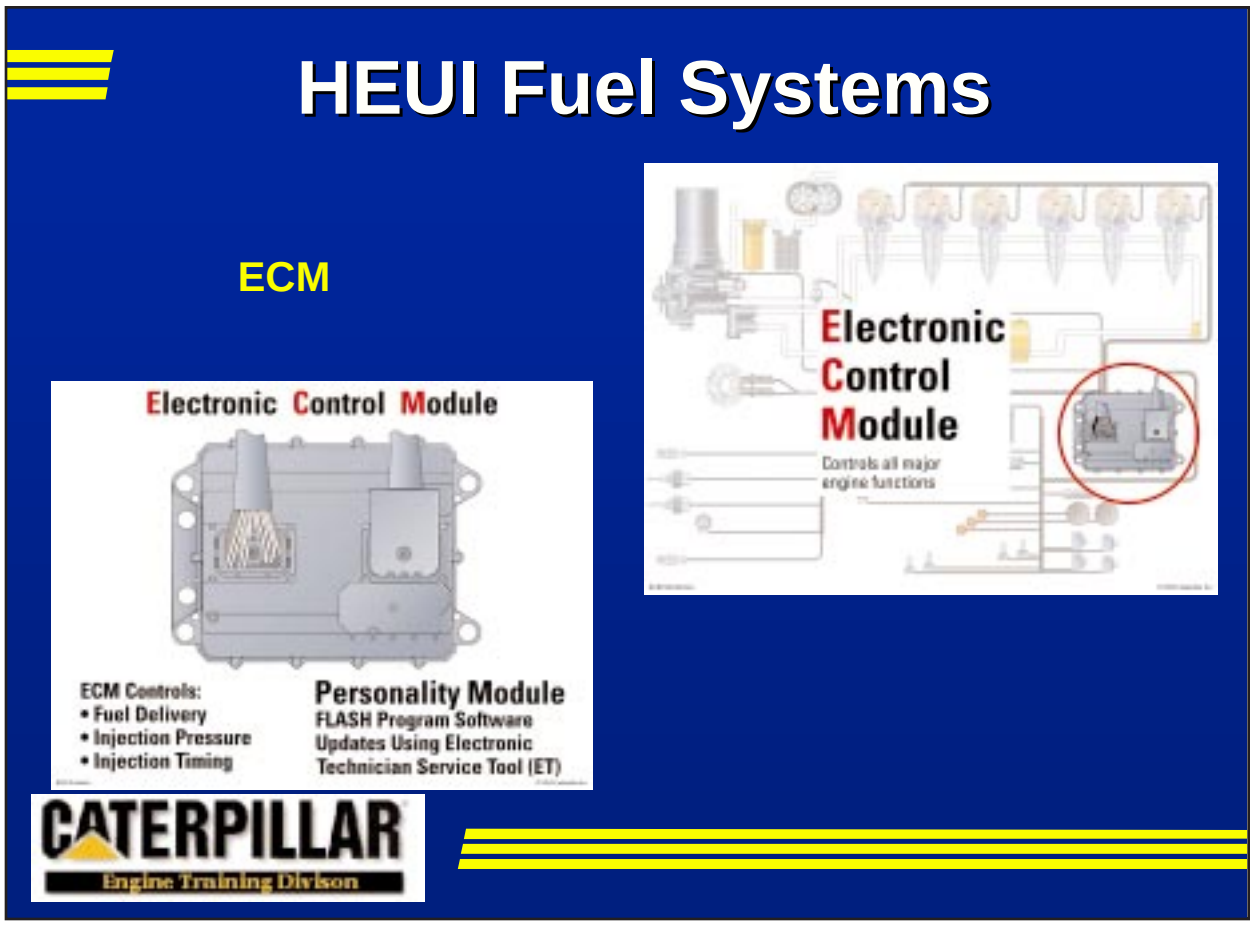
Lets look at the left side of the engine to see where these components are located:

ECM & wiring harness

Hydraulic oil pump including the IAPCV and fuel transfer pump

Oil Manifold

The fuel comes from the fuel tank and primary fuel filter if equipped to the inlet of the fuel transfer pump mounted on the rear of the high pressure oil pump. The fuel transfer pump sends the fuel to a spin on type secondary fuel filter. Fuel from the fuel filter flows through a hard line to a drilled passage in the front of the cylinder head. The drilled passage carries fuel to a gallery around each injector and provides a continuous flow of fuel to all of the injectors. The unused fuel and any air exits the cylinder head at the rear and passes through a pressure regulating orifice and a check valve and returns to the fuel tank.



SLIDE 113

ECM

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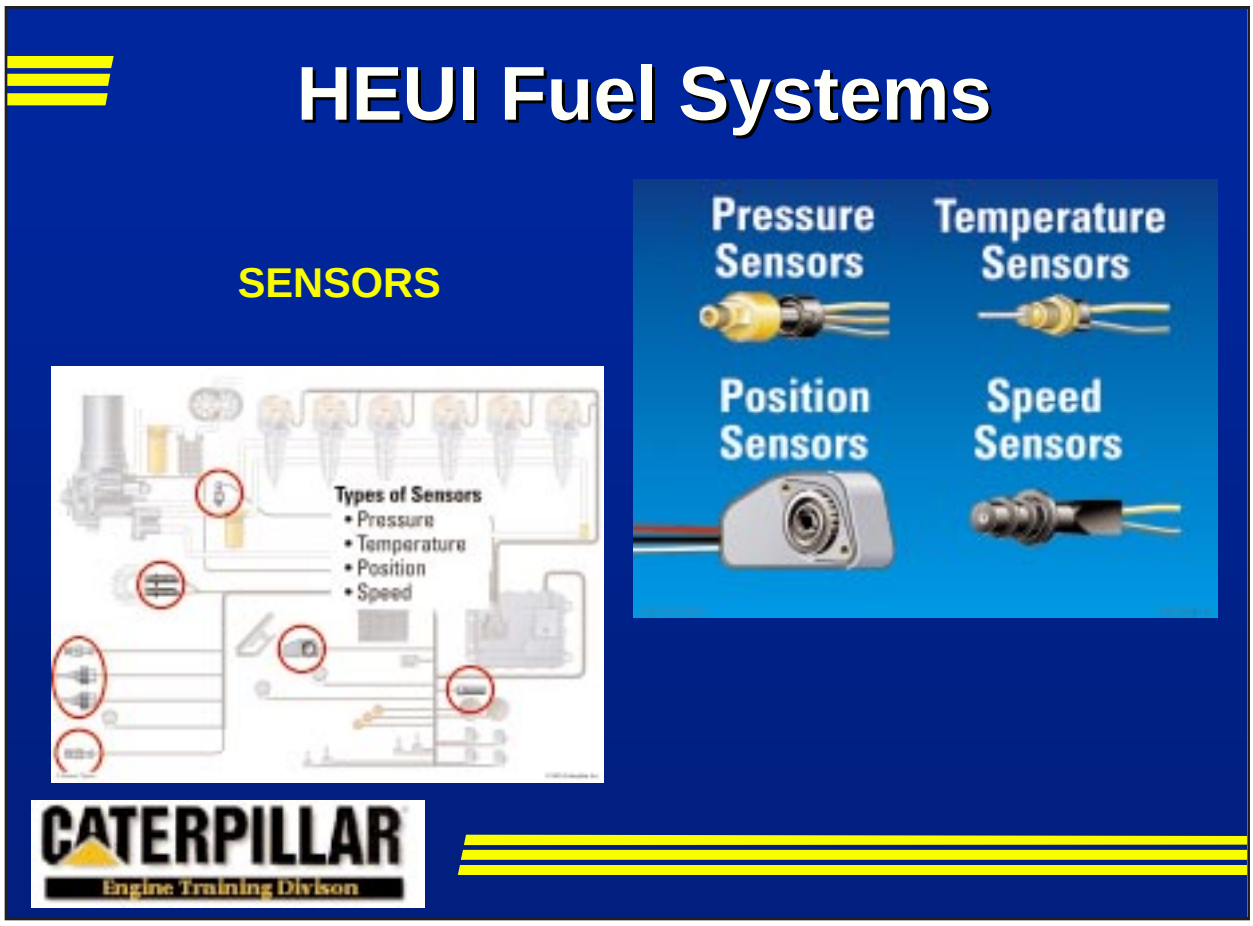


SLIDE 114

For the ECM to control, it must recieve multiple inputs. These inputs are supplied by the various sensors on the engine. Their operation and troubleshooting will be covered in Electronics courses.

SLIDE 115

Engine Rear

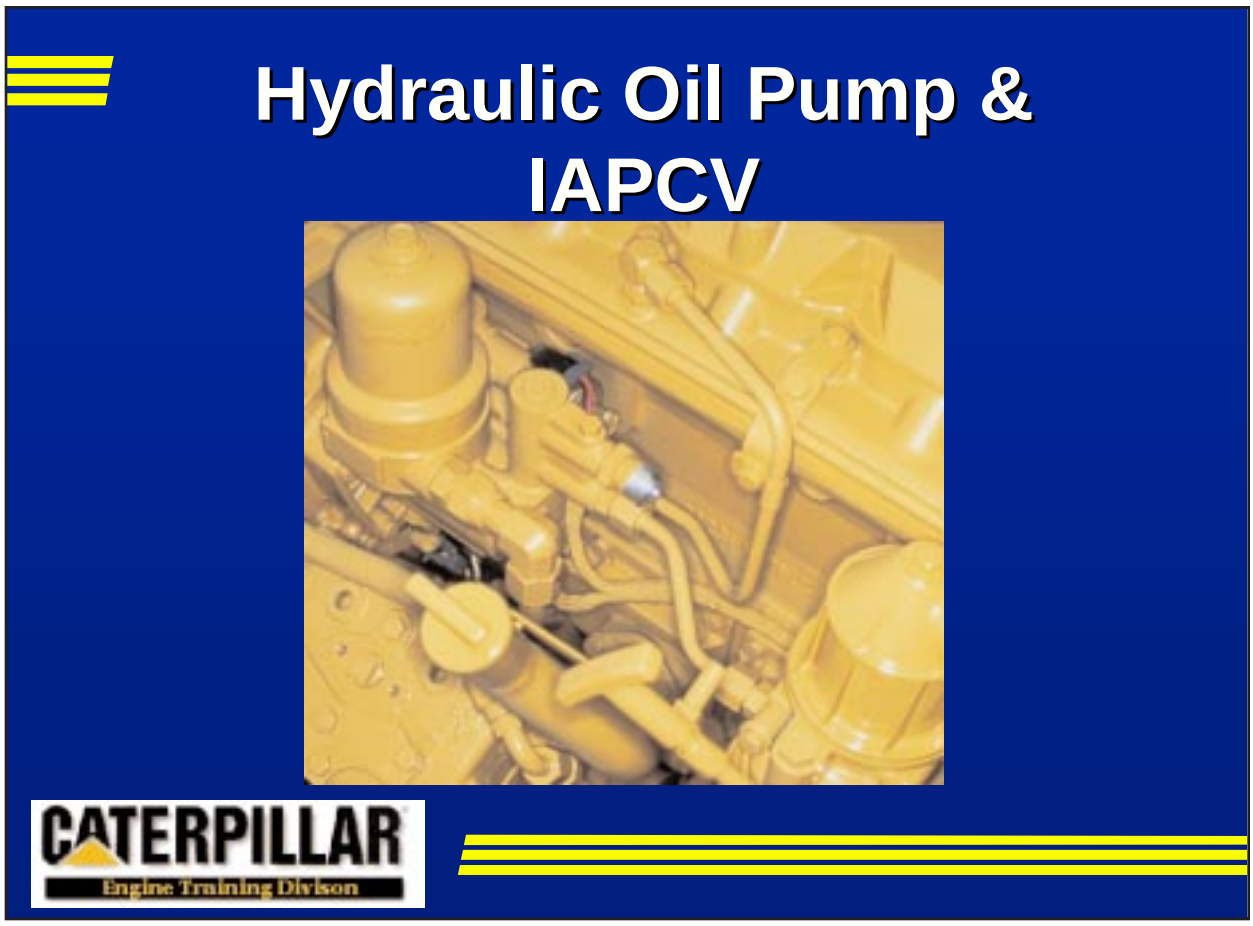
The fuel return check is located in the rear of the cylinder head.

SLIDE 116

Fuel Return Check

0.50 orifice

The fuel return check has a 0.5 mm orifice that maintains fuel pressure in a normal operating range of 58 to 75 psi. The fuel pressure at low idle should be approximately 58 to 63 psi. The check valve prevents the fuel from draining out of the cylinder head and back to the fuel tank when the engine is off.



SLIDE 117

Oil flow through the engine

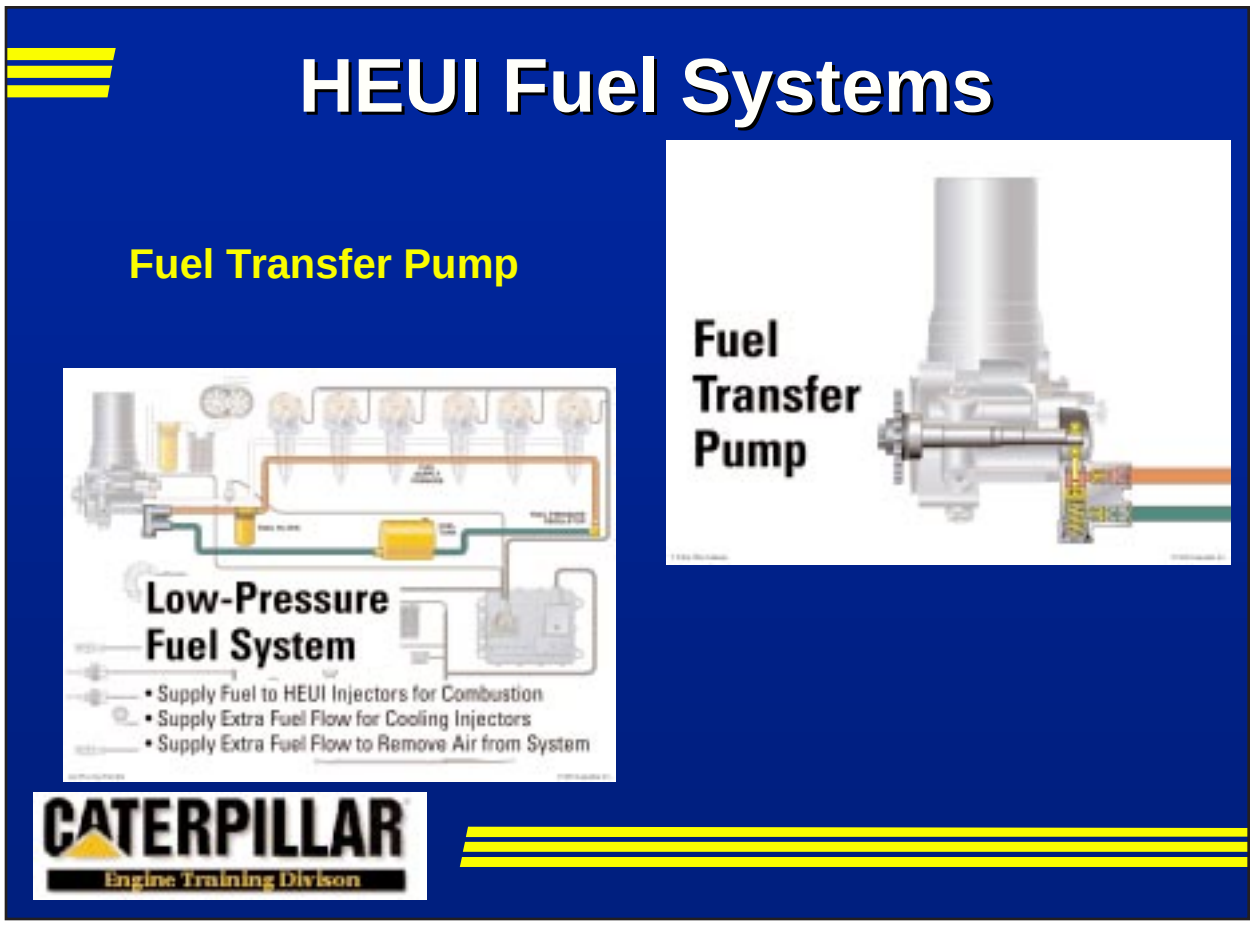
Hydraulic Oil Pump

IAPCV

Fuel Transfer Pump

The oil flow throughout the engine is the same as 1.1 liter engines. The oil for the hydraulic oil system exits the block low on the left side behind the air compressor and flows to the inlet of the high pressure oil pump. Hydraulic oil pressure is controlled by the IAPCV located on the back side of the oil pump. Pressurized oil flows from the pump through a hard line to the high pressure oil manifold.

The fuel transfer pump is driven from the HEUI oil pump and is attached to the rear of of the hydraulic pump.

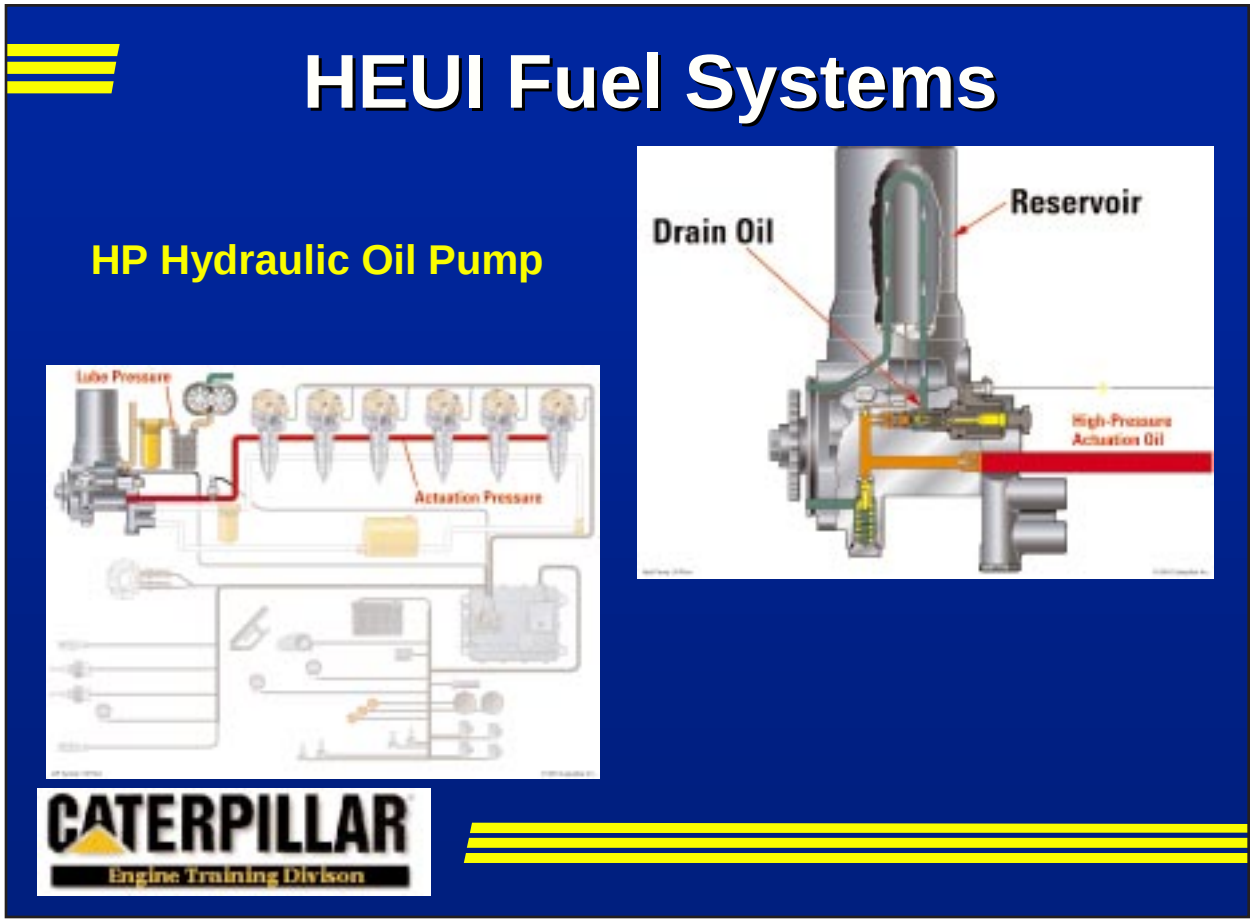


SLIDE 118

Fuel Transfer Pump

The fuel transfer pump is a cam actuated single piston pump which is mounted on the rear of the high pressure oil pump. Fuel system pressure is maintained between 58-76 psi during normal operating conditions under load.

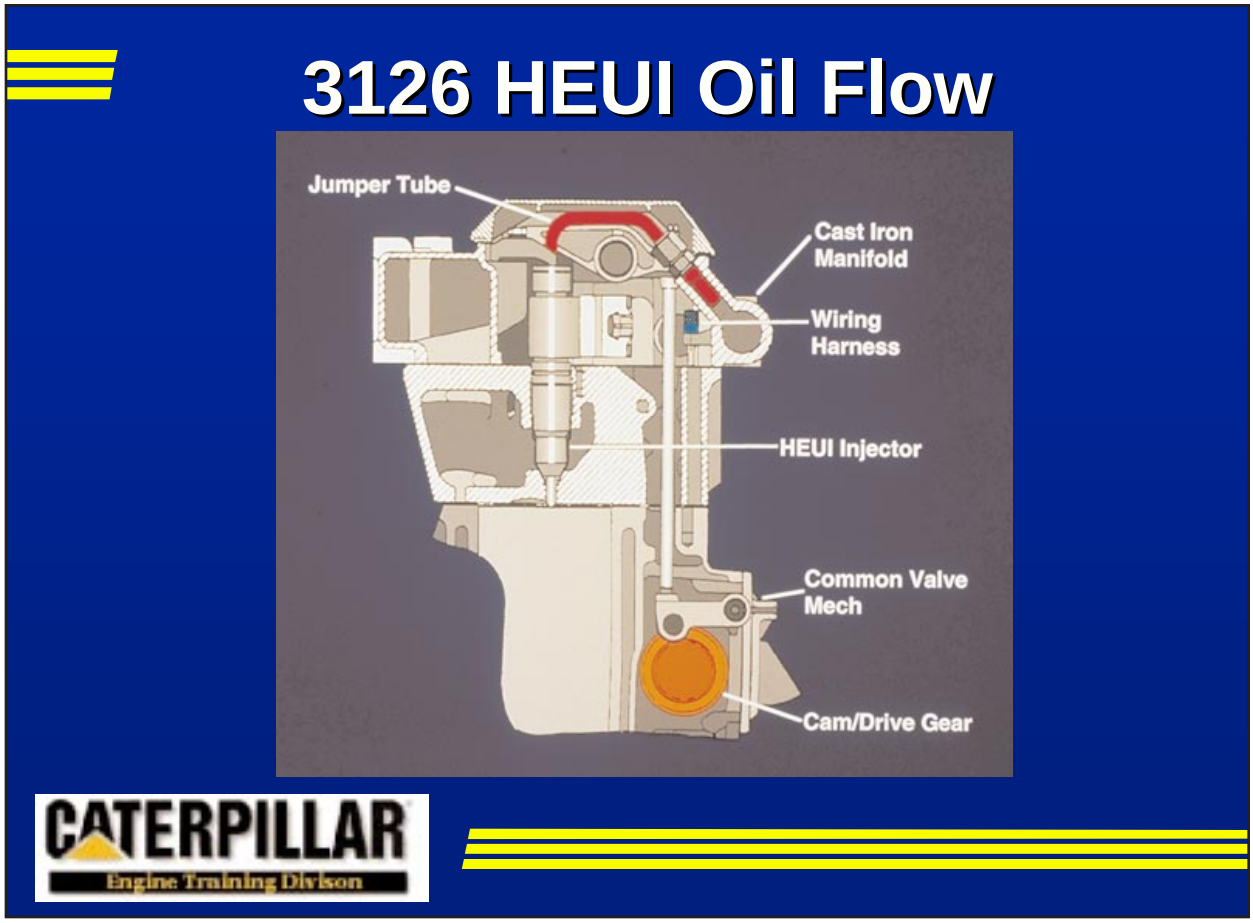
Fuel flows from the pump through the secondary and then through the cylinder head.



SLIDE 119

High Pressure Oil Pump

The hydraulic supply pump is a fixed displacement axial piston pump. During normal engine operation, pump output pressure ranges from 5 MPa (725 psi) to 23 MPa (3335 psi). Output pressure is controlled by the Injection Actuation Pressure Control Valve (IAPCV) which dumps excess pressure and flow back to the return circuit. Pressures for specific engine conditions are determined by the ECM. During cranking, pump pressure is about 5 MPa (725 psi). This was raised to 735 psi on later engines and then raised to 870 psi for the 3126B/E.



Slide 120

Oil flow to the injector

The oil manifold carries the oil to a tuned fitting and individual jumper tubes for each of the injectors. Oil passes through the fitting and jumper tube to the the poppet valve in the top of the injector. The injector uses the oil pressure to actuate the plunger when signaled by the ECM.

SLIDE 121

Tuned fitting

Pressure pulses

Jumper tube seat

The tuned fitting is critical to the operation of the hydraulic system, but shouldn't require any service during the life of the engine. The purpose of the tuned fitting is to prevent pressure pulses, caused by the injector poppet valves opening and closing, from entering the rest of the system. The tuned fitting also serves as a seat for the jumper tube. If the tuned fitting is removed from the manifold, a new o-ring seal should be installed on the fitting

SLIDE 122

Remove HEUI injector

Flare nut

To remove the HEUI injector, first remove the valve cover. Use the 5P0144 Crow's foot wrench to loosen the flare nut that holds the jumper tube to the oil manifold. The 5P0144 is part of the 125-2580 HEUI service tool group.

SLIDE 123

Hold down bolt

Clamp

Remove the injector hold down bolt and clamp.

SLIDE 124

Remove jumper tube

Use the 125-2584 ball head allen wrench to loosen the injector side flange bolts. Disconnect the jumper tube from the oil manifold and the injector and remove the jumper tube from the engine.

SLIDE 125

Removing flange seat

Use caution when removing the jumper tube. The flange seat that sits on top of the injector may move out of position and fall into the engine. The flange seat shown is the original design. On later models, a metal flange was added.

Remove the flange seat from the top of the injector.

SLIDE 126

Remove the O-ring seal

Remove the O-ring seal from the top of the injector. The O-ring seal should be replaced every time the jumper tube is removed.

SLIDE 127

Remove rocker arm assembly

Remove the rocker arm assembly. Be sure to hold the rocker arm assemblies together. Only one end of the rocker arm is pinned.

SLIDE 128

Disconnect wiring harness

Disconnect the wiring harness from the injector. Care should be taken not to break the retaining clips on the connector. A repair kit is available for connector replacement, but it can be used only one time for an individual connector due to the length of the wire. The weather pak seal should be replaced whenever the wiring harness is disconnected.

SLIDE 129

Remove the injector

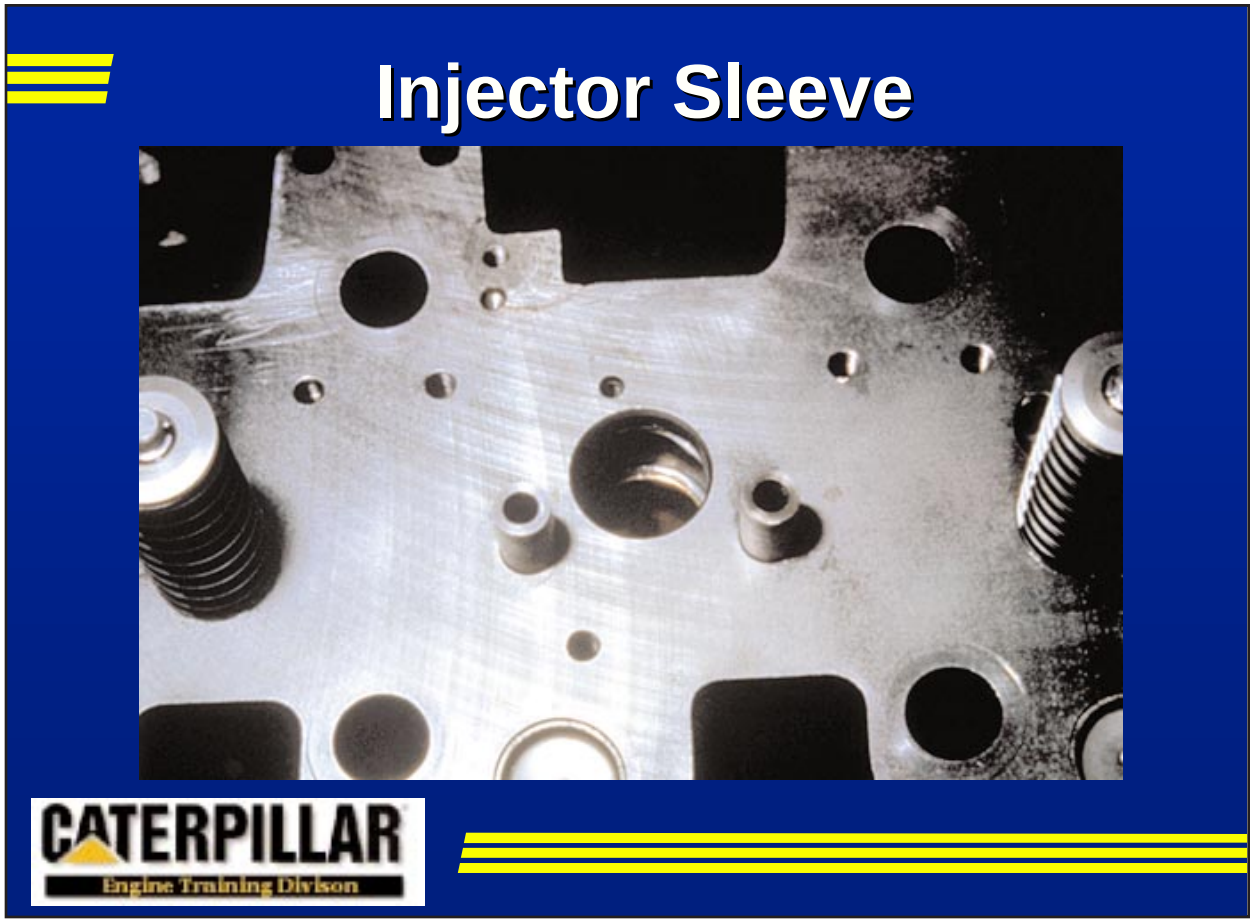
Remove the injector from the cylinder head. First try to remove it by hand. If it can not be worked loose, use the 1U7587 pry bar to loosen the injector in the head. CAUTION: Pry only on the main body of the injector, not the multi piece screwed on section as this could cause non-warrantable injector failure.

SLIDE 130

Pry on the injector body

Pry only on the injector body. DO NOT pry on the solenoid or solenoid adapter. Prying on the solenoid or solenoid adapter can cause misalignment between the poppet valve and the injector body.

An o-ring seal is shown at the bottom of the injector. This was present on all older injectors. The new ones do not have it and it should be removed on the old ones. The o-ring was there to serve as a temporary seal until carbon began to build up. It was removed since its presence reduced clamping force.



SLIDE 131

Replace injector sleeve

Interference

Tool Group

Once the injector has been removed, the injector sleeve can be replaced if necessary. Use the 143-2099 Sleeve Replacement Tool Group to replace the injector sleeve. Follow the procedure in the Special Instruction for the 143-2099 Sleeve Replacement Tool Group,Form No SEHS9120.

The HEUI injector sleeve is 1.0 mm shorter than the ones used on the MUI engines in the past. Installation of an earlier MUI injector sleeve will cause interference between the sleeve and the injector and the injector will not seat properly. These older sleeves were canceled and replaced by the new ones.

The 143-2099 Sleeve Replacement Tool Group consists of the 127-3462 Sleeve Replacement Tool Group and the 127-3460 Sleeve Replacement Tool Group.

SLIDE 132

Install injector

Weatherpack seal

Put clean engine oil on the injector O-ring seals. Put the injector in place in the cylinder head and push down on top of the injector to seat it in the bore.

Install a new weatherpack seal on the wiring harness and connect the wiring harness to the injector.

SLIDE 133

Install rocker arms

Install flared seat

Install jumper tube

Install the rocker arm assemblies.

Install the O-ring seal in the groove on top of the injector, and put the flared seat in position on top of the injector.

Install the jumper tube. Hand start the manifold end nut first and then line up and hand start the bolts on the injector end. Tighten the bolts and flare nut hand tight.

SLIDE 134

Jumper tube installation

Tightening procedure

Adjust valves

Install valve cover

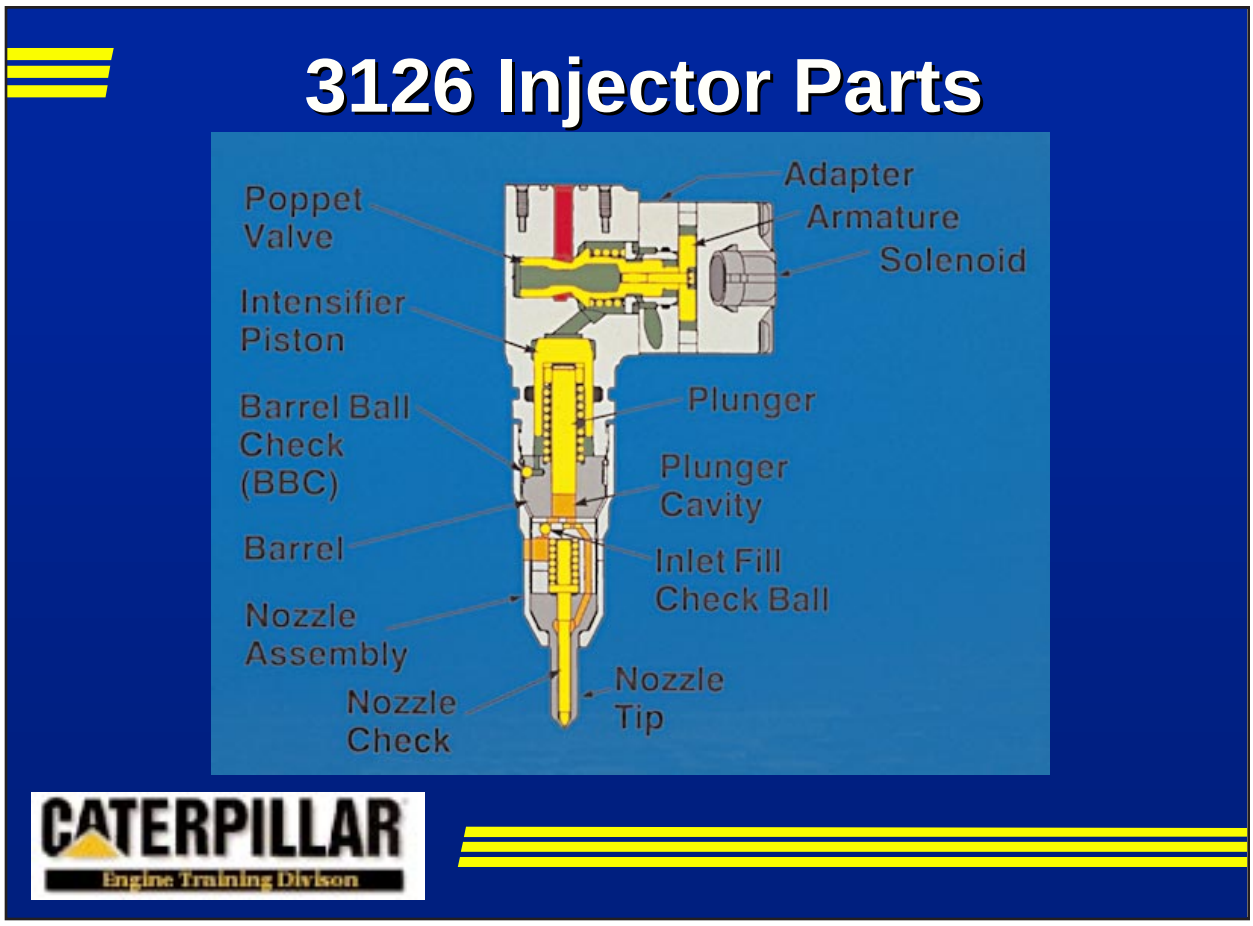
A special tightening procedure is required to insure the jumper tube is seated properly on both ends. First, put the 125-2583 clamping fixture in place on top of the jumper tube where the injector hold-down clamp normally attaches. Rotate the injector in the cylinder head to align the jumper tube bolt with the hole in the clamping fixture. Tighten the clamping fixture bolt to a torque of 36 N•m (26 lb ft).

Next, tighten the manifold end of the jumper tube to a torque of 40±5 N•m (29±4 lb ft).

With the clamping fixture still in position, tighten the bolts on the injector end of the jumper tube to a torque of 3 N•m (27 lb in). Tighten the bolts again to a torque of 6 N•m (53 lb in).

Remove the clamping fixture and install the injector hold down clamp. 36 N•m (26 lb ft)

Adjust the valves and install the valve cover.



SLIDE 135

Five major components

Solenoid

Poppet valve

Intensifier piston and plunger

Barrel

Nozzle assembly

The HEUI injector has has five major components:

SOLENOID

The solenoid is a very fast acting electromagnet, which when energized, pulls the poppet valve from its seat to the oil drain seat, which opens the injector to high pressure oil and closes the oil drain.

POPPET VALVE

The poppet valve is held on its seat by a spring. In this closed position, the high pressure inlet oil is blocked and the intensifier cavity is opened to drain.

When the solenoid is energized, the poppet is lifted off its seat. The path to drain is closed and the inlet for high pressure oil is opened.

INTENSIFIER PISTON AND PLUNGER

When the poppet valve opens the inlet port, high pressure oil enters the

injector and acts on the top of the intensifier piston. Pressure builds on the intensifier, pushing it and the plunger down. The intensifier piston is approximatelty 7 times larger in surface area than the plunger providing a multiplication of force. The downward movement of the plunger pressurizes the fuel in the plunger cavity, causing the nozzle to open. A large O-ring around the intensifier separates the oil above the piston from the fuel below it.

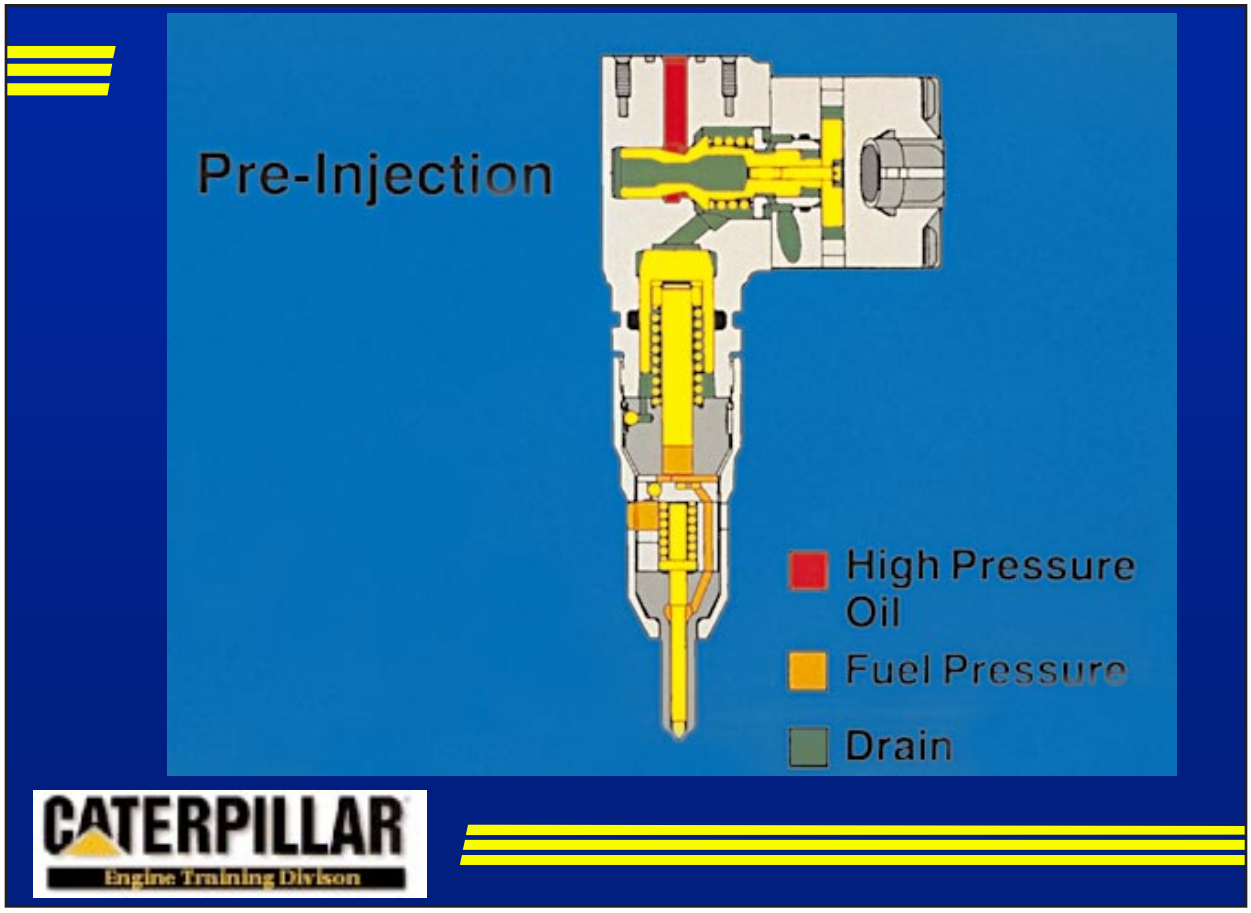
BARREL

The barrel contains a cross drilled hole with a spring loaded check ball. This is called the Barrel Ball Check or BBC. It's purpose is to vent any fuel which leaks between the plunger and barrel into the intensifier piston cavity. If this cavity were allowed to fill with fuel, the plunger would be very sluggish during injection and fuel delivery would be greatly reduced. The downward stroke of the piston during injection creates a positive pressure which unseats the spring loaded ball and exhausts any leakage. The spring reseats the ball to prevent pressurized fuel on the outside from leaking in.

NOZZLE ASSEMBLY

The nozzle assembly is of conventional design with the exception of the inlet fill check ball and reverse flow check plate. The inlet fill check ball unseats during upward travel of the plunger to allow the plunger cavity to refill. It seats and seals during the downward stroke of the plunger to prevent injection pressure from leaking out to the fuel supply.

The reverse flow check is a one way check plate which allows fuel to enter the nozzle assembly, but closes to prevent reverse flow at the end of injection. It traps fuel pressure in the nozzle to prevent combustion gas from entering the nozzle if the there is leakage between the nozzle tip and check. Without the reverse flow check, a severe tip leak could allow combustion gas to accumulate in the nozzle. At low fuel delivery conditions, such as idle, this combustion gas would compress and the nozzle would not reach Valve Opening Pressure (VOP). The injector would not deliver fuel and would become a dead cylinder.



SLIDE 136

Four stages

- Pre-injection
- Initial injection
- Main injection
- Return

Pre-injection stage

There are four stages of injection with the HEUI:

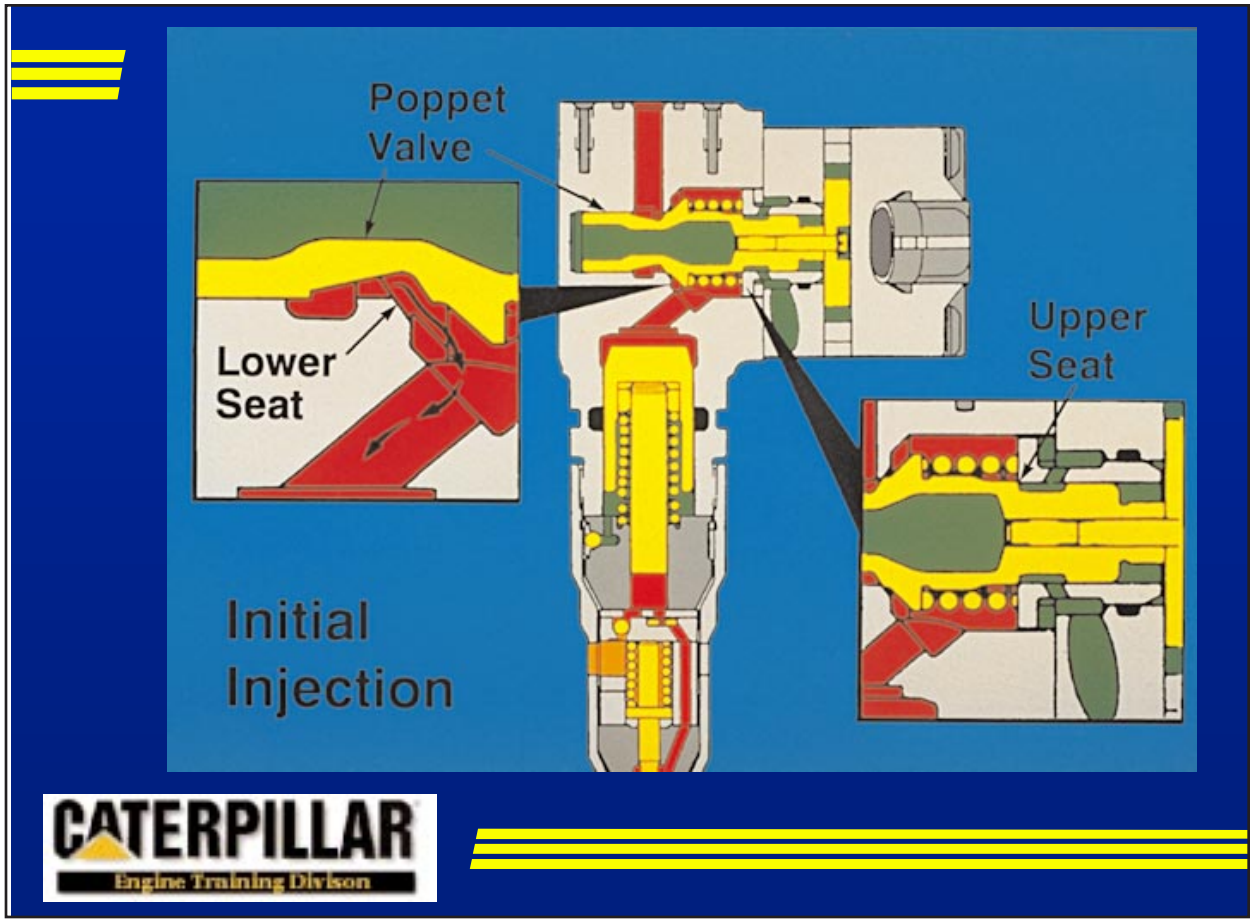
Pre-Injection

Initial Injection

Main injection

Return Cycle

During pre-injection all internal components have returned to their spring loaded (non-actuated) position. The solenoid is not energized and the poppet valve is blocking high pressure oil from entering the injector. The plunger and intensifier are at the top of their bore and the plunger cavity is full of fuel. Fuel pressure in the plunger cavity is the same as transfer pump pressure, approximately 60 psi.

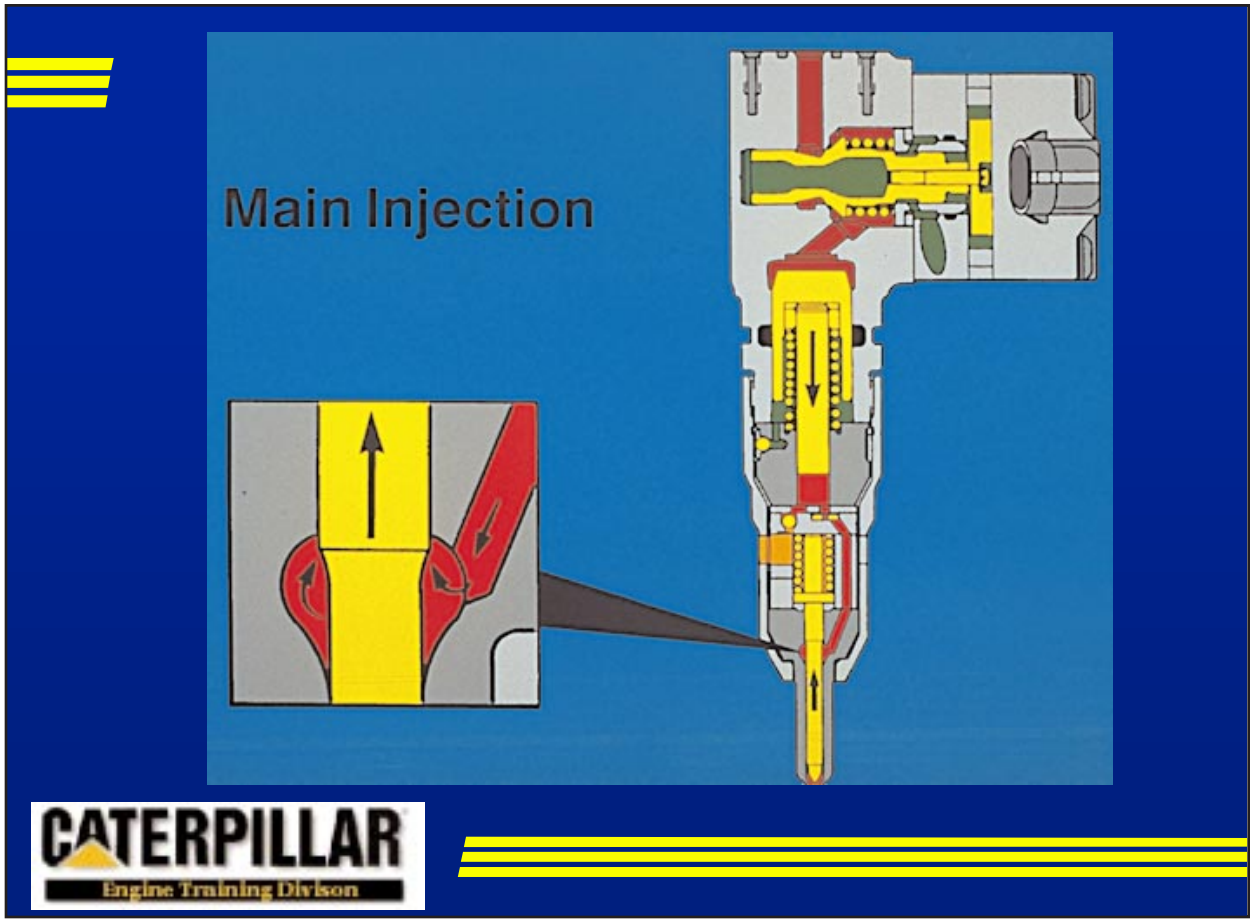


SLIDE 137

Initial injection

When the ECM determines that the injector should be fired, it sends the correct electric current pulse to the injector solenoid. The solenoid is fully energized almost instantly, creating a strong magnetic pull on the armature. The armature is mechanically connected to the poppet valve by a screw. The magnetic pull of the solenoid overcomes the spring tension holding the poppet closed and raises the poppet off its seat, and at the same time.closing the drain port.

When the poppet valve opens, the upper poppet land closes the path to drain and the lower land opens the poppet chamber to incoming high pressure oil. High pressure oil flows around the poppet through the passage to the top of the intensifier piston. Pressure on the top of the intensifier forces it down along with the plunger. The downward movement of the plunger pressurizes the fuel in the plunger cavity and nozzle. When the pressure reaches Valve Opening Pressure (VOP) of about 4,500 psi, the nozzle check valve lifts off its seat and injection begins.



SLIDE 138

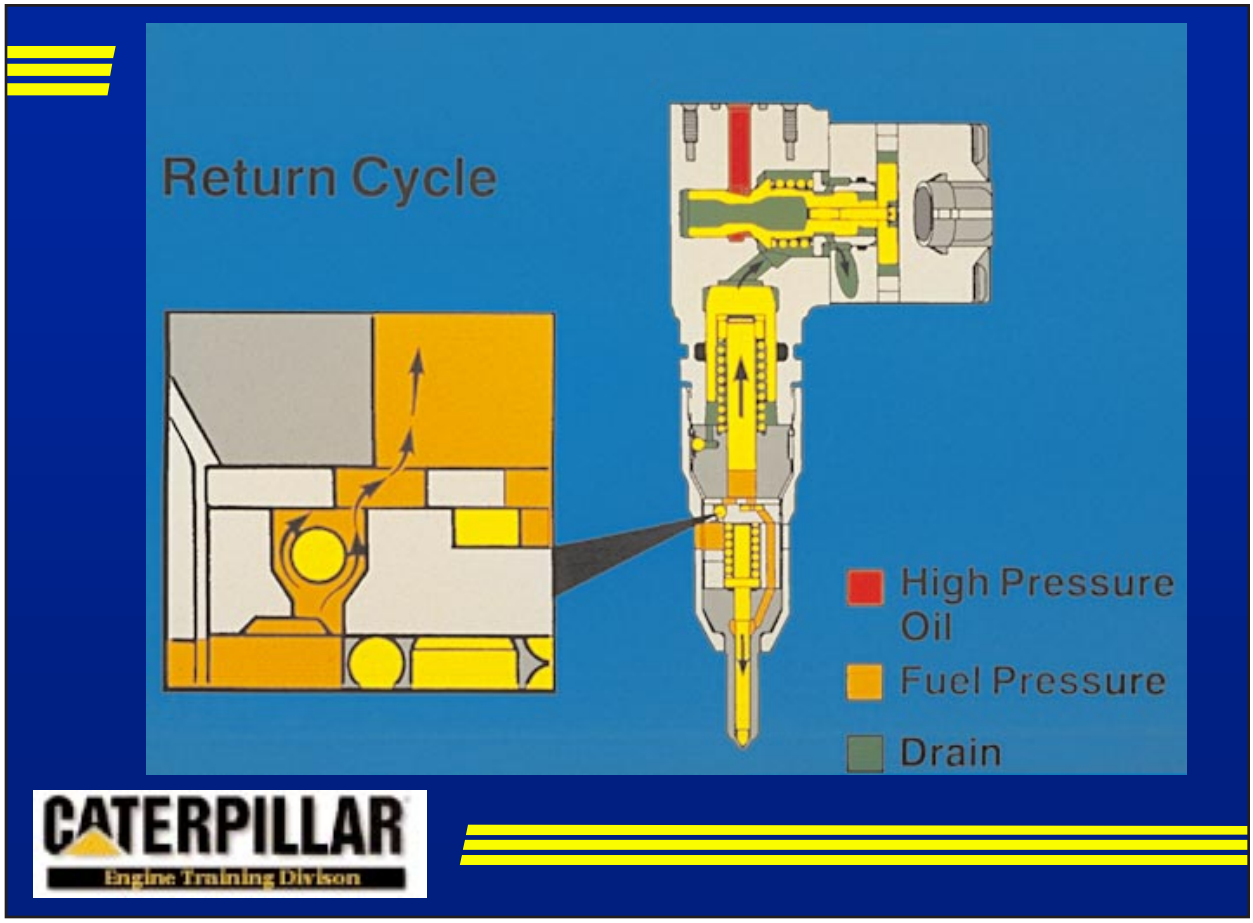
Main injection

Stroke limiting

As long as the solenoid is energized, the poppet remains open and pressure oil continues to flow in pushing down the intensifier and plunger. Injection pressure ranges from 5,000 - 23,000 psi depending on engine requirements. Injection continues until one of the following conditions occur:

1) The solenoid is de-energized allowing the poppet spring to close the poppet and shut off the high pressure oil.

2) The intensifier hits the bottom of its bore. This would be maximum fuel delivery. The distance from the bottom of the intensifier to the bottom of its bore is a controlled distance to limit maximum fuel delivery. This feature is called Stroke Limiting. It prevents electronic tampering from increasing maximum fuel delivery beyond maximum intended fuel rates.



SLIDE 139

Return cycle

The end of the injection cycle begins when the ECM terminates the current to the solenoid. The magnetic field of the solenoid collapses and is no longer able to overcome poppet spring tension to hold the poppet off its seat. The poppet closes, shutting off high pressure oil from entering the injector. When the poppet is seated, the upper land of the poppet opens the poppet cavity to drain. Pressurized oil in the intensifier chamber and poppet chamber can now flow upward around the poppet seat, through the vent holes in the poppet sleeve and out the adapter drain hole.

The pressure of the fuel in the plunger cavity and the plunger return spring exert an upward force on the plunger and intensifier. As the pressure of the downward force on the intensifier decreases. The upward force from the pressurized fuel and spring almost instantly becomes greater than the downward force on the intensifier so the downward motion of the intensifier and plunger reverses.

When the plunger stops, fuel flow also stops. With the check still open, the remaining pressure on the fuel pushes a tiny amount of additional fuel out the orifice holes. This causes a large pressure drop which lowers nozzle pressure below Valve Closing Pressure (VCP) of 2,700 psi. Spring tension on the check now reseats the check and injection stops.

VCP 2700 - Lower than VOP

Instructor Note: VCP is lower than VOP because more surface area of the check is exposed to pressurized fuel when the check is off its seat.

When the check closes, injection stops and the fill cycle starts. The poppet and intensifier cavities are open to atmospheric pressure through the poppet valve and adapter drain hole. Pressure drops very rapidly in the intensifier and plunger cavities to near zero. The plunger return spring pushes upward on the plunger and intensifier forcing oil around the poppet, through the holes in the poppet sleeve and out the adapter drain hole.

As the intensifier moves up, the barrel ball check closes to prevent fuel from filling the area under the intensifier. This causes a partial vacuum in this area so that the volume of fuel is about 3/4ths of cavity volume. This feature prevents a high pressure spike in the fuel rail when the injector fires. If this cavity was filled with fuel, a large volume would be forced back into the fuel rail as the intensifier rapidly moved downward during injection. The resulting pressure spikes would cause pressure variation and idle instability.

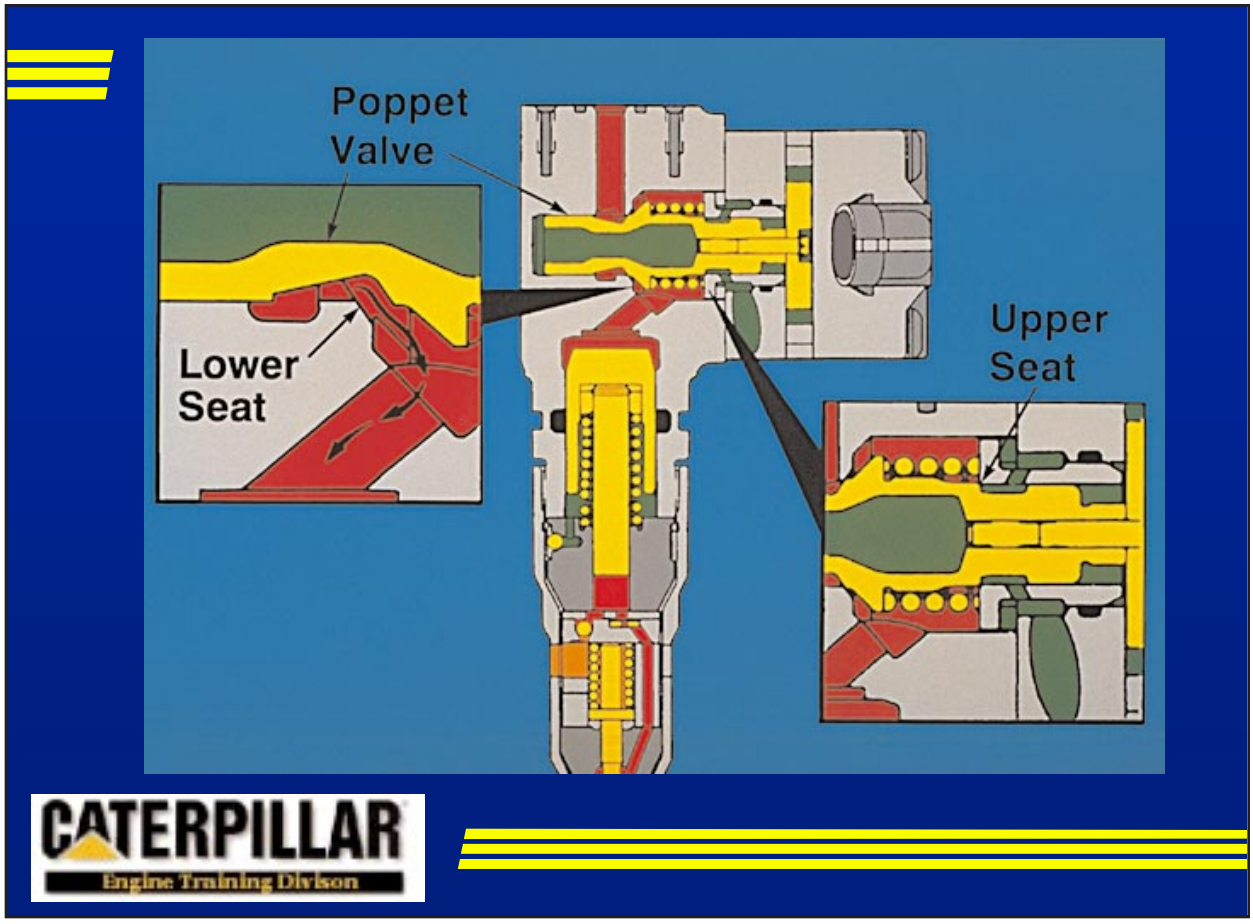
As the plunger rises, pressure in the plunger cavity also drops to near zero. The transfer pump pressure unseats the inlet fill check ball allowing the plunger cavity to fill with fuel.

The fill cycle ends when the intensifier is pushed to the top of its bore. The plunger cavity is full and the fill check returns to its seat. Pressure in the intensifier and poppet chambers is zero. The injection cycle is complete and is ready to begin again.

Now that we have a good understanding of HEUI operation, let’s briefly discuss another key difference between the HEUI and all other mechanically driven fuel systems. That difference is that HEUI injection is time based, and tends to compensate for leakage between the plunger and barrel.

In mechanical systems, plunger speed is a function of crankshaft speed. As wear occurs between the plunger and barrel, the leakage rate increases. This increased leakage results in reduced fuel delivery as wear becomes excessive.

The HEUI plunger is hydraulically driven and speed is a function of actuation pressure versus fuel pumping resistance. If plunger and barrel wear increases leakage, the fuel pumping resistance is reduced and the plunger will move faster and farther to compensate. The result is that injection pressure will be maintained and the desired amount of fuel will be delivered through the nozzle even though leakage has increased. This remains true until wear becomes so severe that the plunger cannot accelerate fast enough during short injections to compensate or the plunger literally runs out of travel when the intensifier piston bottoms out against the barrel.



SLIDE 140

Injector replacement

Poppet seat alignment

This completes the mechanical operation of the injector. Now, let's discuss injector servicing.

INJECTOR REPLACEMENT

If injector replacement is necessary, the injector is replaced as a unit. There are no serviceable parts on the injector except the 0- rings on the outside.

DO NOT attempt to disassemble the injector under any circumstances. A performance test and detailed analysis will be done on every injector returned from the field. Injector disassembly will cause the injector to be non-functional and fail the performance test. It is very easy to determine if an injector has been disassembled or abused during removal. Let's take a few minutes to discuss why.

POPPET SEAT ALIGNMENT

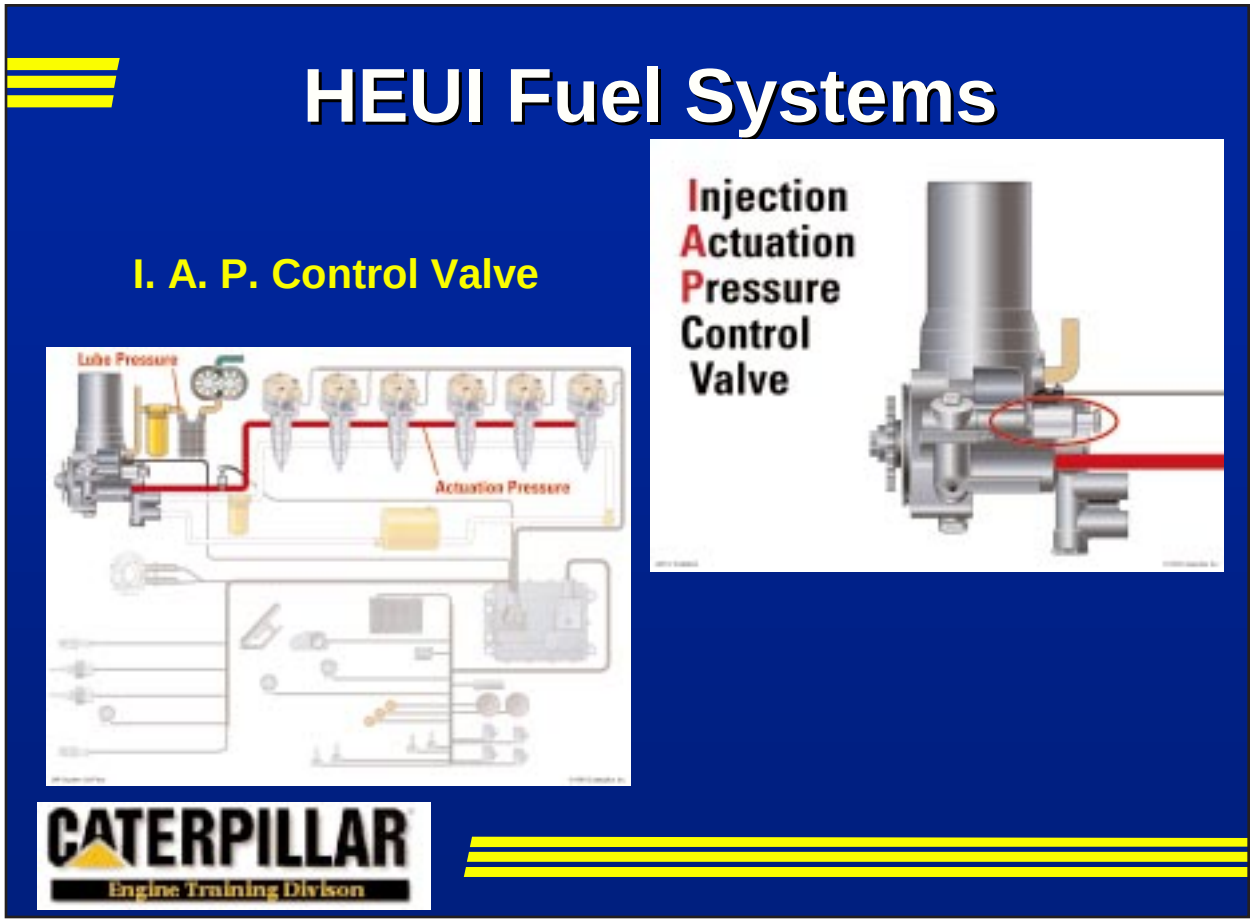
The injector poppet valve has an upper and lower seat which must both

seal perfectly for the injector to work. The poppet is guided by upper and lower guides. The lower guide is ground into the body below the lower seat. The upper guide is ground into the poppet sleeve above the upper seat. The poppet sleeve is located in the adapter. Correct poppet alignment is achieved by precise location of the adapter. The adapter is clamped to the body by four screws located underneath the solenoid. The screw holes in the adapter have enough clearance to allow the adapter to be moved to achieve correct alignment. This alignment can only be done by a robotic assembly machine and cannot be done by hand.

If the alignment of the adapter is not correct, the upper poppet seat will not seal and the injector will have a massive upper seat leak. The adapter is not doweled to the body. It is held in position only by the axial force of the adapter screws which clamp it to the body. If the adapter screws are loosened or removed, the alignment is lost and the injector is scrap. It cannot be aligned manually in the field. If reinstalled in the engine with an upper seat leak, the injector will not fire and will fail the upper seat leak test on the bench test when it is returned for analysis. Massive upper seat leak on the test is a sure indication that the injector was disassembled or that the adapter was pried on and moved during injector removal.

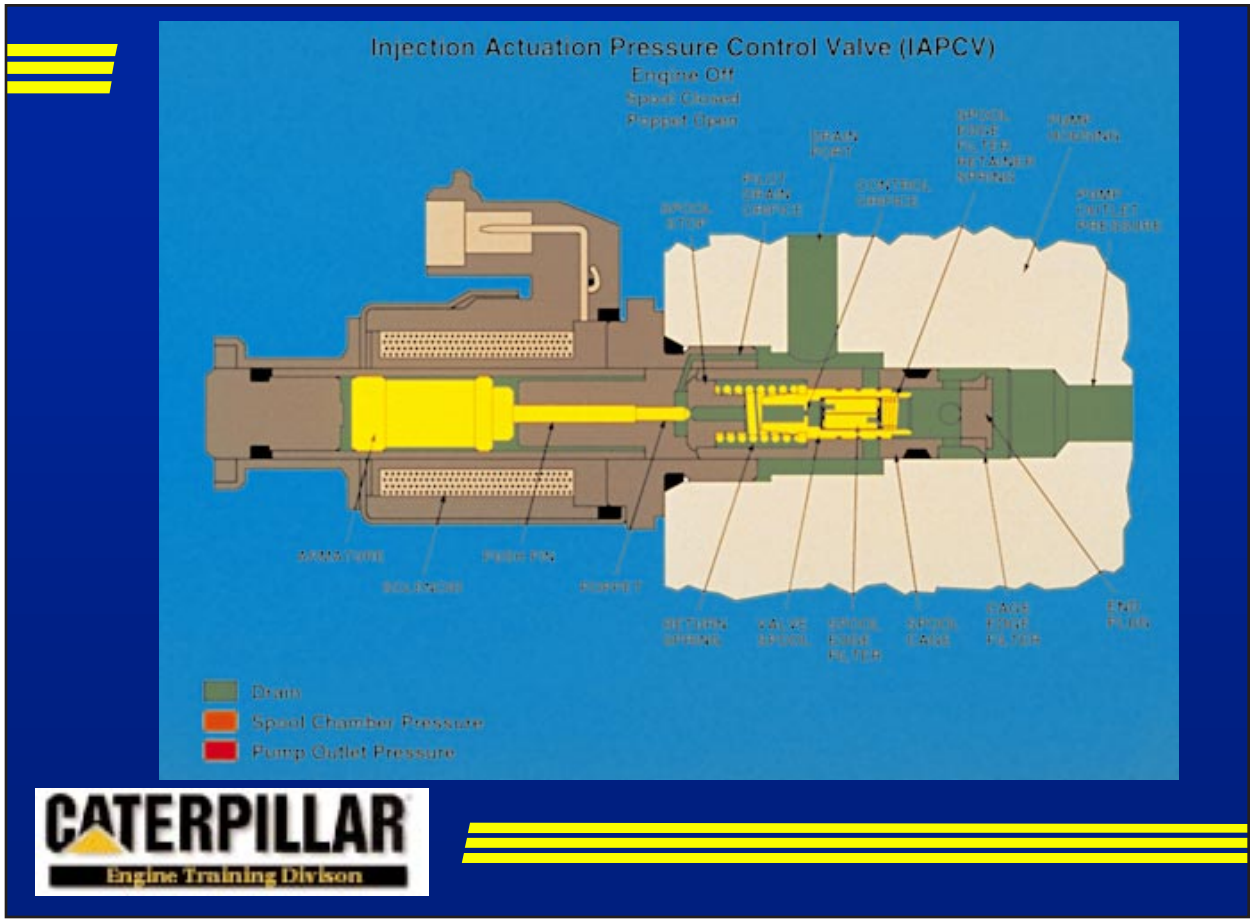
INJECTOR REMOVAL FROM THE CYLINDER HEAD

Adapter alignment can also be lost by prying on the adapter during injector removal. The injector can be removed by twisting and pulling up by hand, or prying up under the the injector body. Prying up on the adapter will cause adapter movement and loss of poppet alignment. Prying on the solenoid will cause it to break.



SLIDE 141

If we must control injection pressure with high pressure oil, then we must have a way to control the HEUI oil supply pressure. This is done by use of an IAPCV (Injection Actuation Pressure Control Valve) mounted on the HEUI oil pump.



SLIDE 142

Injection actuation pressure control valve

Fixed pump displacement

Engine off

The IAPCV is located on the inboard side of the hydraulic pump, between the pump and the engine block on the 3126/3116 and on the outboard side on the 3126B/E. The IAPCV is an electrically controlled pilot operated pressure control valve. This valve is required for two reasons.

First, the pump is a fixed displacement style pump. As engine rpm increases, pump flow increases. There are many conditions where pump flow is much greater than what is required by the injectors. This excess flow must be dumped to drain with precision and very fast response time.

Second, a variable displacement pump would eliminate excess pump flow, but could not react to pressure and speed changes fast enough. This would result in pressure overshoot and undershoot during rapidly changing pressure demands. The IAPCV and fixed displacement pump can maintain the desired actuation pressure regardless of variations in

engine rpm and pump flow.

The basic components of the IAPCV are the:

- Body
- Spool
- Spool spring
- Poppet
- Push pin
- Armature
- Solenoid
- Edge filter

The IAPCV operates by using a variable voltage electrical signal from the ECM to create a magnetic field in the solenoid. This magnetic field acts on the iron armature and generates a mechanical force, pushing the armature to the right. This force is transmitted through a push pin to the small poppet valve.

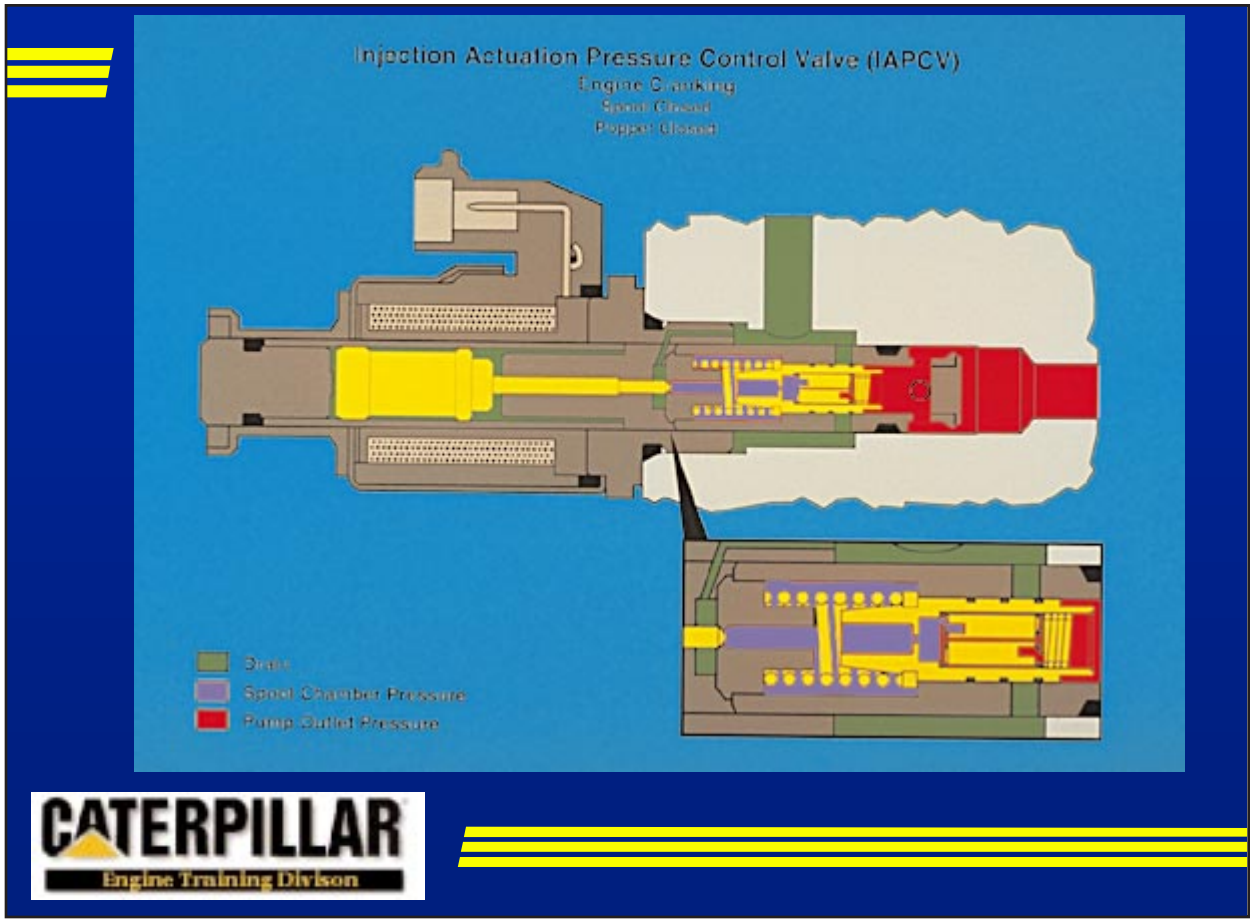
The mechanical force trying to hold the poppet closed is opposed by reduced hydraulic pressure inside the valve trying to open the poppet. This reduced hydraulic pressure will increase until the two forces are in equilibrium. The more current supplied to the solenoid, the higher the resultant hydraulic pressure. Less current results in lower pressure.

The reduced pressure inside the valve is combined with spring pressure and acts on the spool to push it to the right and close off the drain ports. Pump pressure acts on the other side of the spool to push it to the left and open the drain ports. These hydraulic forces also reach equilibrium.

The net result is that pump pressure is controlled by the electrical signal to the solenoid.

OPERATION - ENGINE OFF

The illustration above shows the position of the spool with the engine off. With no hydraulic pressure, the spring pushes the spool all the way to the right, closing off the drain ports.



SLIDE 143

Engine cranking

5 MPa (725 psi) required to start

Pressure sensor

ECM determines pressure

Oil flow through IAPCV

In first production engines approximately 5 MPa (725 psi) of oil pressure is required to fire the injector during start-up. This was later increased to 735 psi and then to 870 psi for the 3126B/E. This low actuation pressure generates a very low injection pressure. The low injection pressure causes the nozzle check to open and close rapidly, putting small squirts of fuel into the combustion chamber which aids starting.

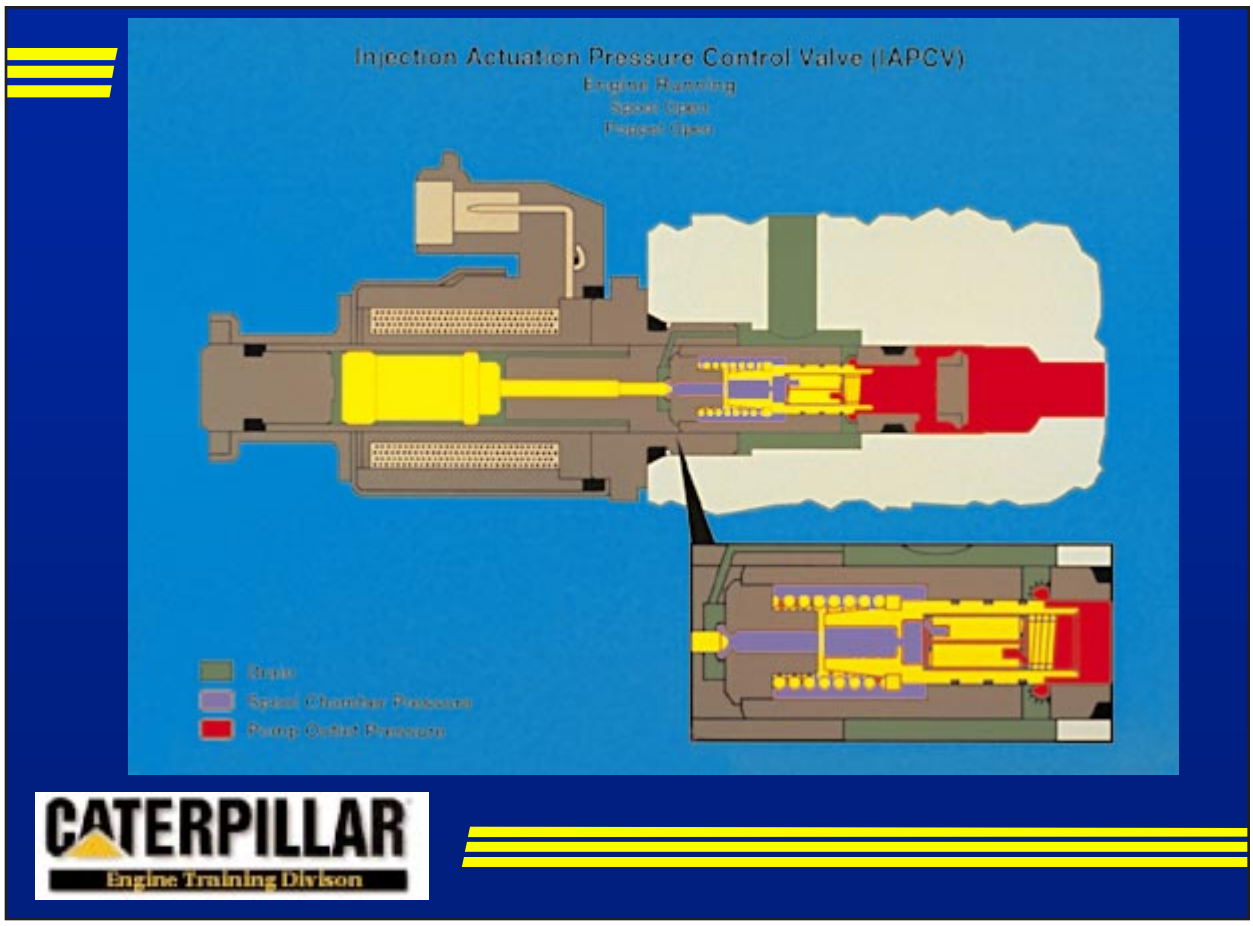
In order to start the engine quickly, the actuation pressure must rise quickly. Since the pump is being turned at engine cranking rpm, pump flow is very low. The ECM sends a strong current to the IAPCV solenoid to hold the spool closed and block all flow to drain until the appropriate minimum actuation pressue is reached. The injectors are not fired until the appropriate minimum actuation pressue is reached.

Once the injectors begin to fire, the ECM controls the current to the IAPCV to maintain appropriate minimum actuation pressue until the

engine starts. The ECM monitors actuation pressure through the Injection Actuation Pressure Sensor located in the oil manifold. This is a closed loop system. The ECM determines the desired pressure based on several inputs, and sends a predetermined current to the IAPCV. The ECM also compares the desired pressure to the actual pressure in the manifold and makes adjustments to IAPCV current levels to achieve the desired pressure.

OIL FLOW - ENGINE CRANKING

Pump outlet pressure (red) enters the end of the body and a small amount of oil flows into the spool chamber (blue) through the edge filter and control orifice in the end of the spool. The electronic signal causes the solenoid to generate a magnetic field which pushes the armature to the right. The armature exerts a force on the push pin and poppet holding the poppet closed allowing spool chamber pressure to build. The combination of spool spring force and spool chamber pressure hold the spool to the right closing the drain ports. All pump flow is directed to the oil manifold until appropriate minimum actuation pressure is reached.



SLIDE 144

Engine Running

Oil flow through IAPCV

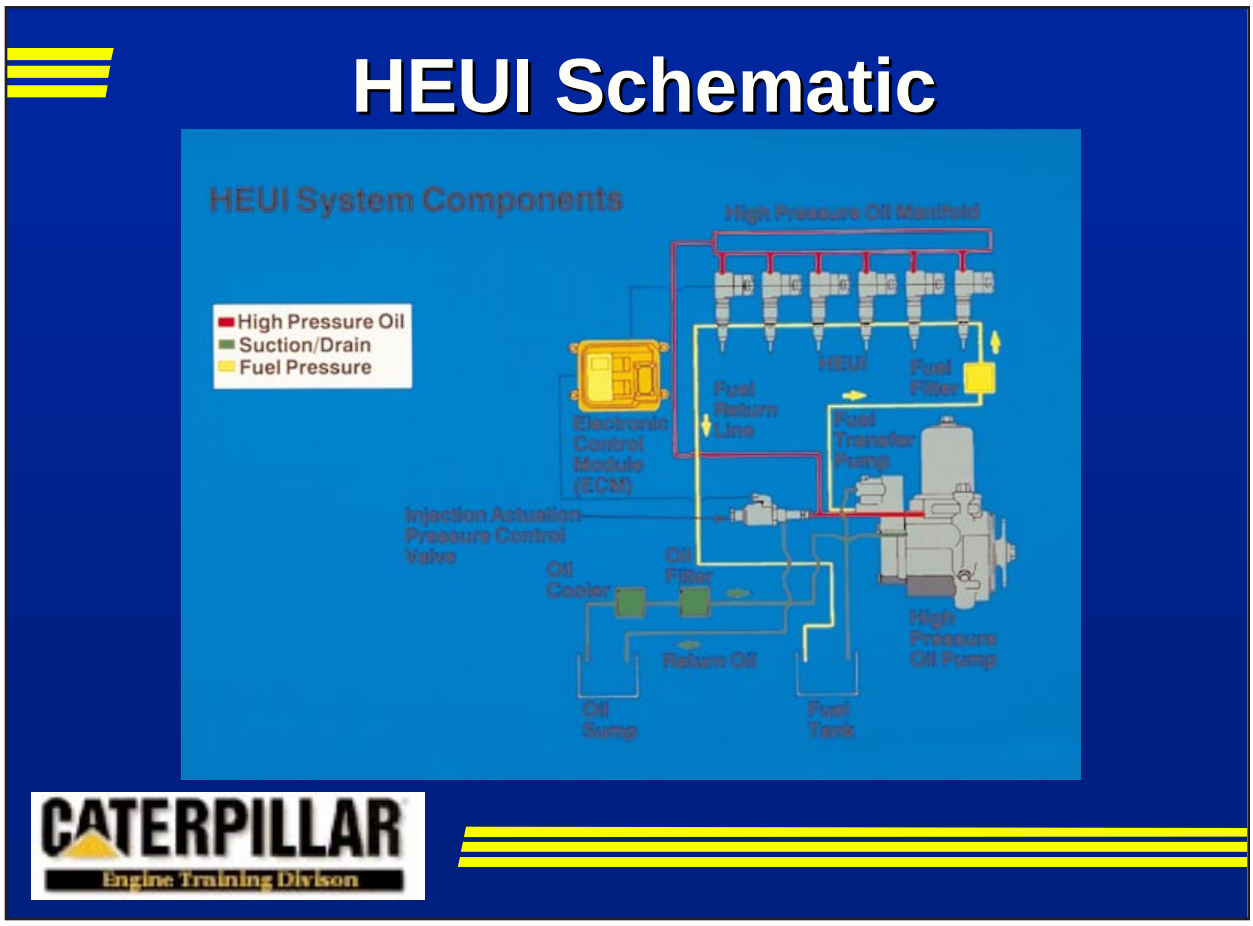
725 to 3335 psi

Once the engine starts, the ECM controls the current to the IAPCV to maintain the desired actuation pressure. The Injection Actuation Pressure Sensor monitors actuation pressure in the oil manifold, and the ECM compares actual pressure to desired pressure. If these pressures do not match, the ECM adjusts the current level to the IAPCV to compensate.

OIL FLOW - ENGINE RUNNING

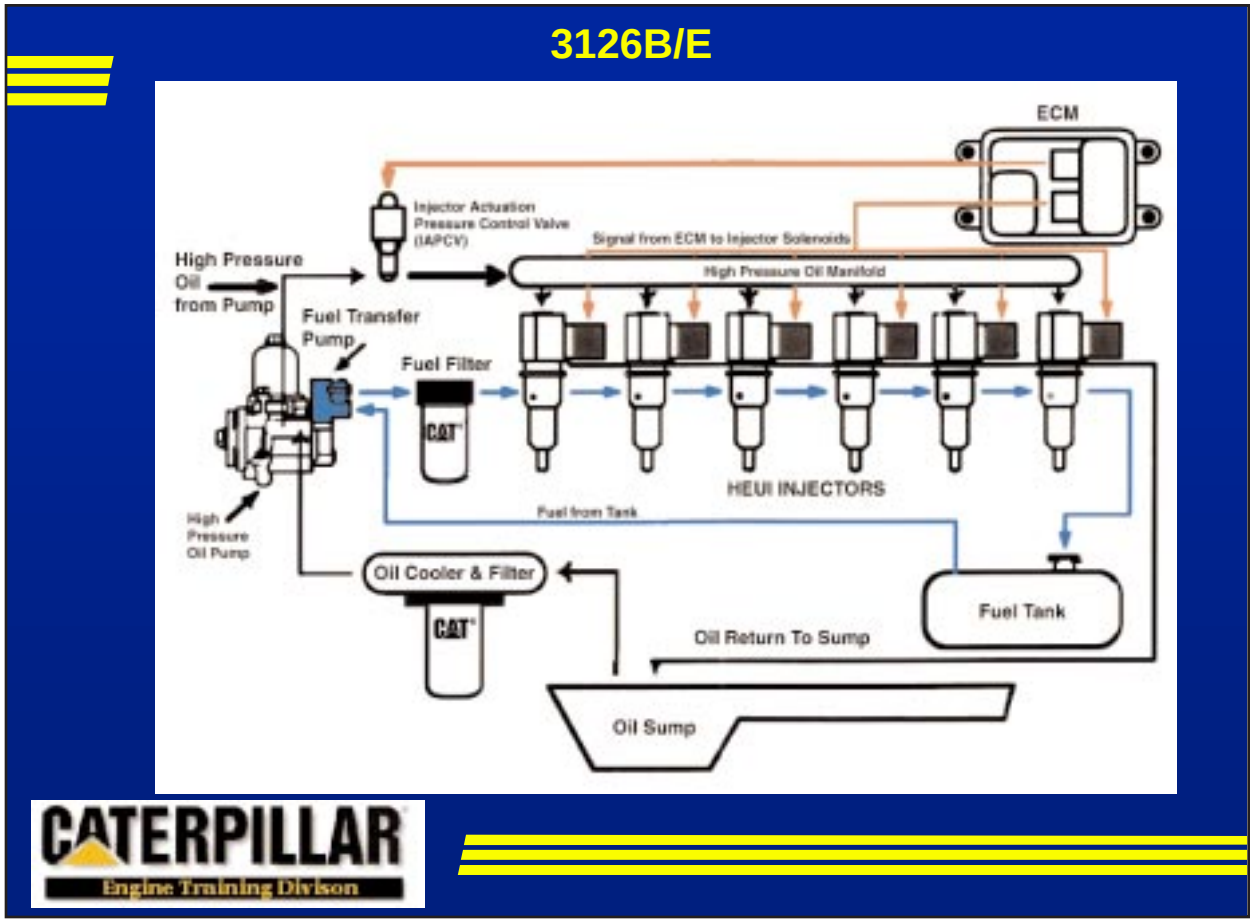
Pump outlet pressure (red) enters the end of the valve and a small amount of oil flows into the spool chamber through the edge filter and control orifice in the spool chamber. The pressure in the spool chamber is controlled by the force on the poppet and allowing it to bleed off some of the oil in the spool chamber. The force on the poppet is controlled by the strength of the magnetic field produced from the electrical signal from the ECM. The spool responds to pressure changes in the spool chamber (left side of the spool) by changing positions to

maintain a force balance between the right and left side of the spool. The spool position determines how much area of the drain ports are open. The drain port open area directly affects how much oil is bled off from the pump outlet and directly affects rail pressure. The process of responding to pressure changes on either side of the spool occurs so rapidly that the spool is held in a partially open position and pump outlet pressure is closely controlled. The IAPCV allows infinitely variable control of pump outlet pressure between 725 psi (5MPa) and 3,335 psi (23 MPa).



SLIDE 145

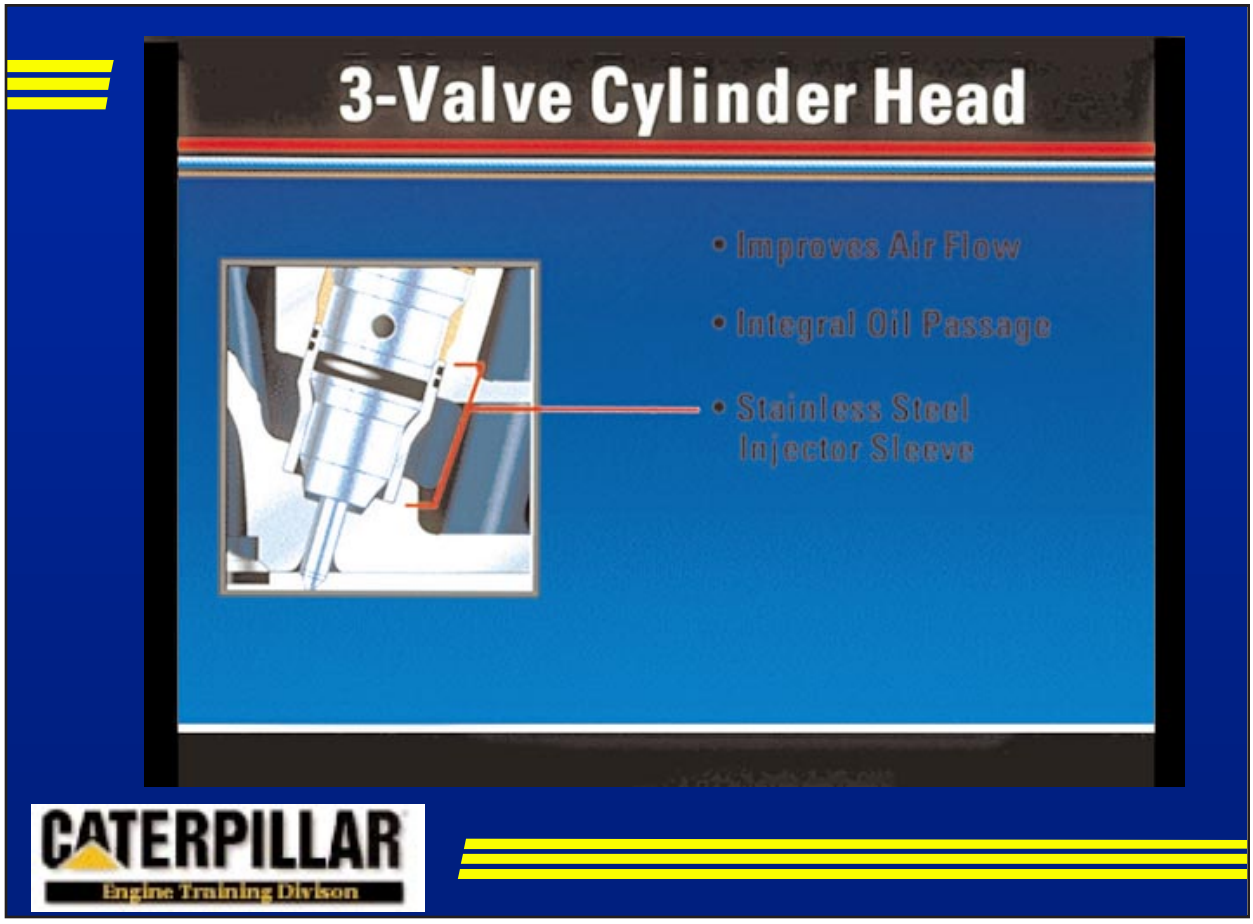
Again we look at the schematic of the 3126 HEUI to review it prior to looking at the 3126B/E schematic.



SLIDE 146

Little Schematic Change

With the 3126B/E, the schematic looks a bit different, but it is the same in principle. The major difference is the elimination of the jumper tubes that supply oil to the injector. The oil supply now comes through the cylinder head.



SLIDE 147

Now let's discuss the changes that came with the 3126B/E product. The 3126B/E doesnot have the brass injector sleeve. It uses a stainless steel replaceable sleeve. This sleeve is similar to the C-10 and C-12 injector sleeve.

The stainless steel injector sleeve replacement is easier and faster. The entire process for sleeve replacement is described in the Disassemble and Assemble manual for sleeves without the threads cut in to the sleeve itself. Some of the engines were built with this style sleeve.

A new design sleeve has been released which already has the threads cut into the top of the sleeve.

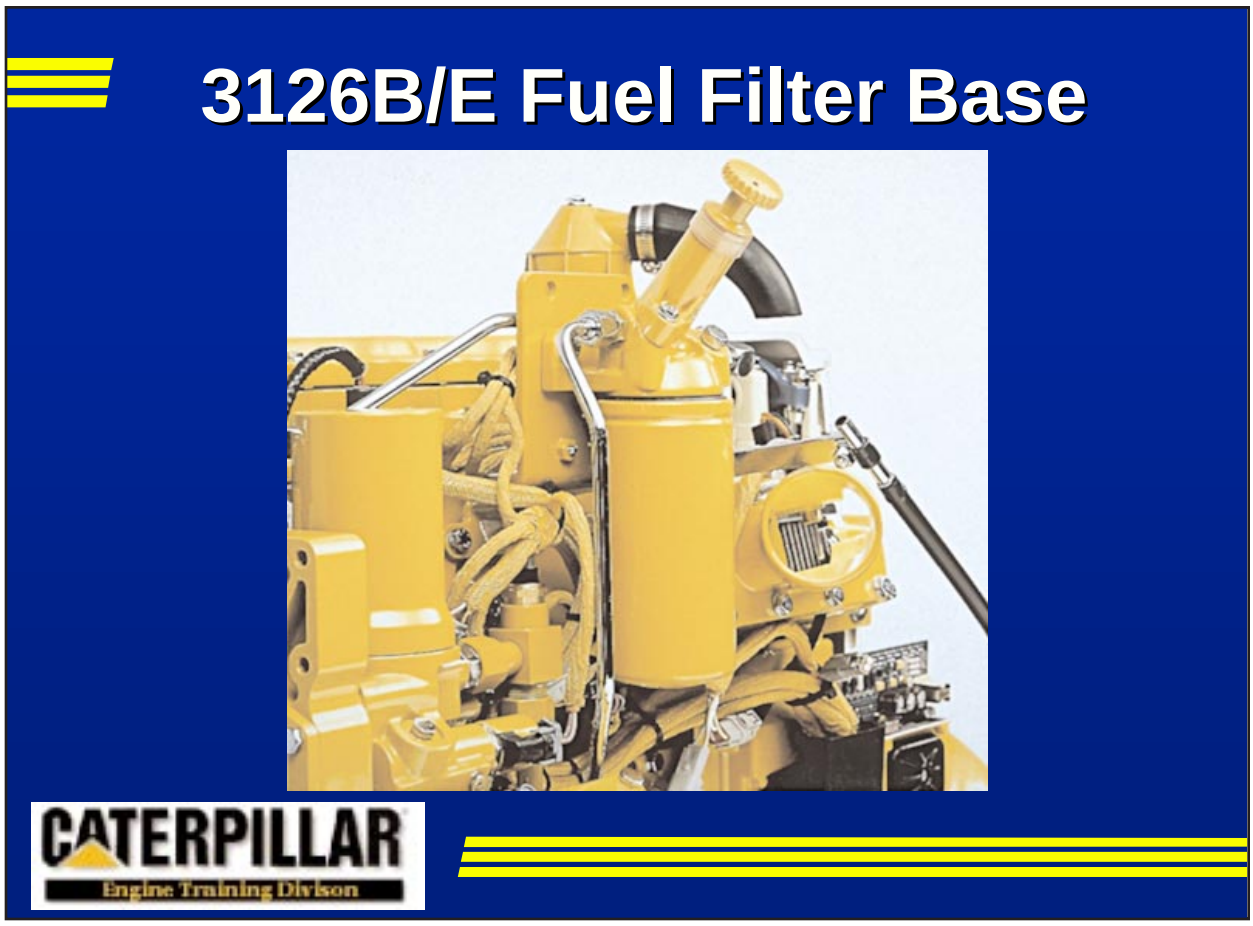
SLIDE 148

3126B/E HEUI Unit Injector

HI300 Angled

Does not use a jumper tube design

The 3126B/E (HI300) unit injector does not use jumper tubes for oil supply. The oil is supplied directly to the middle portion of the injector and is sealed by two seal rings. The unit injector has a top mounted solenoid. The wiring harness has shared commons between injectors 1 & 2, 3 & 4, and 5 & 6. The injector also has a connector for easier removal and installation of the wiring harness.



SLIDE 149

Fuel filter location

Hand priming pump standard

High Pressure Oil Pump

Slight increase in pump displacement

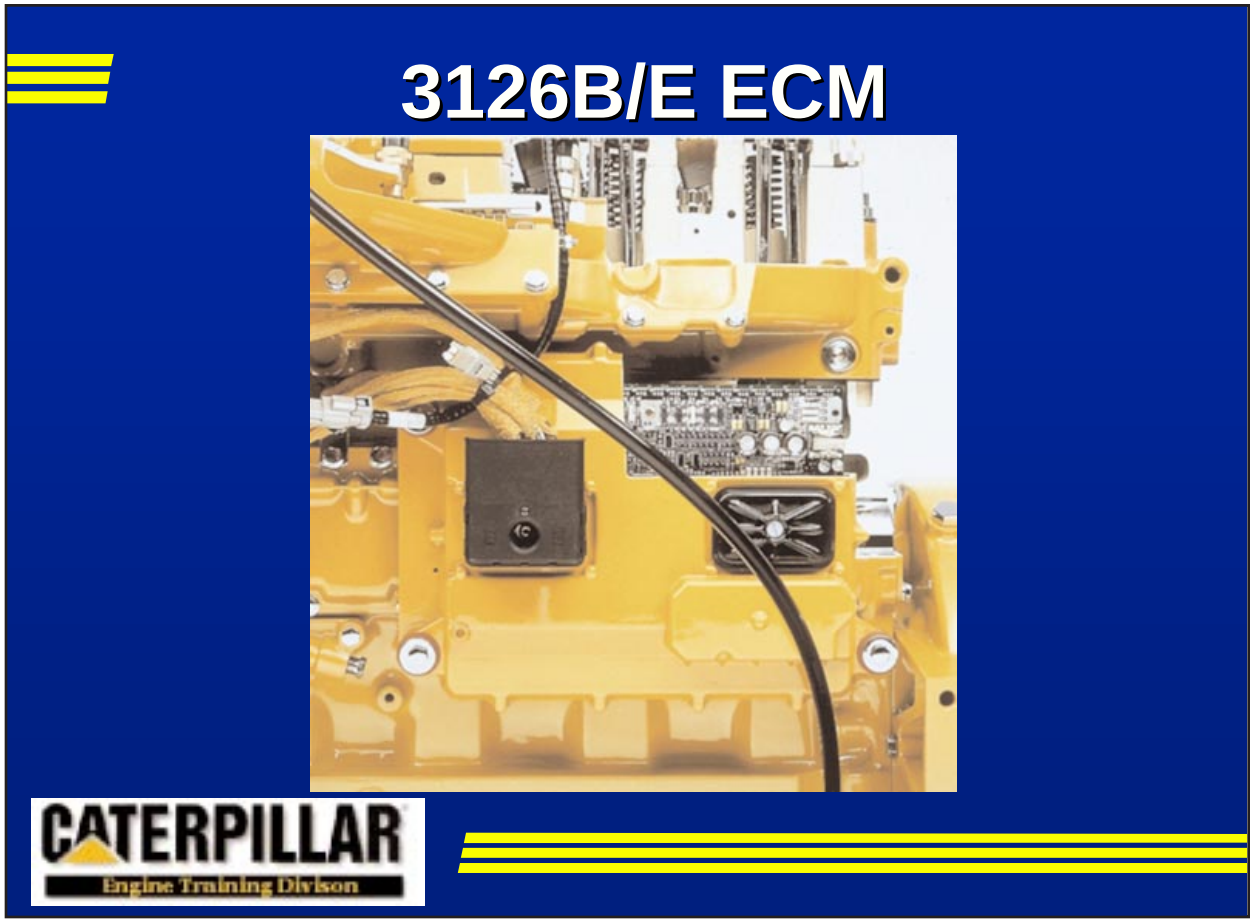
IAPCV relocated for easier access

With the 3126B/E, the intake manifold was been moved to the left side of the engine the fuel filter was been relocated to a higher location. With this change we have easier access for filter replacement.

With the introduction of the model change, we recieved the addition of a hand priming pump. The hand priming pump is standard on most models.

The HEUI pump looks a bit different with a squared top instead of rounded and has a slight increase in pump displacement.

The IAPCV was been moved to the outside of the pump for easier access of valve replacement. Other than these two changes the pump is primarily the same.



SLIDE 150

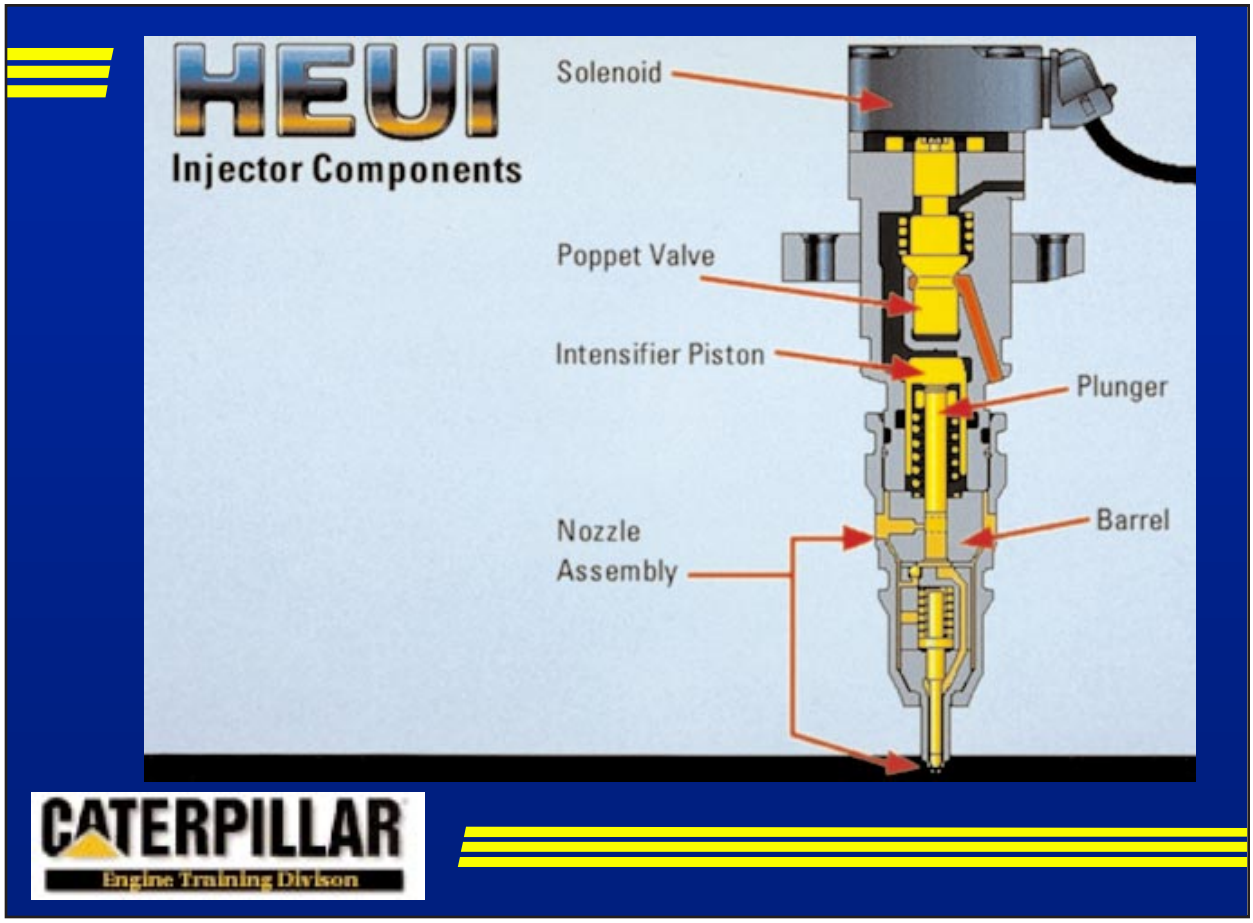
ECM

Seventy Pin Connectors

Faster processor

ECM terminals must be gold

The 3126B/E is equipped with the ADEM 2000 Electronic Control Module. The ADEM 2000 is equipped with two seventy pin connectors. The connectors used on the wiring harness are a Deutsch type. The ECM Terminals, in the connector, must be gold. This ECM also has a faster processor than the ADEM 2 allowing for more customer features.



SLIDE 151

The HEUI injector has several different configurations. The one used on the 3126B/E is the HI300. This stands for:

Hydraulic Injector (Angled) 300 cubic millimeters per stroke displacement.

The HEUI is hydraulically actuated by high pressure engine oil supplied by a fixed displacement axial piston pump. Pump outlet flow and pressure is controlled by an electronic pressure relief valve(IAPCV). The HEUI injector has five major components:

SOLENOID

The solenoid is an electromagnet. When the solenoid is energized, the solenoid creates a very strong magnetic field. This magnetic field attracts the armature which is connected to the poppet valve by an armature screw. When the armature moves toward the solenoid, the armature lifts the poppet valve off the poppet valve's lower seat.

Energizing the solenoid and lifting the poppet valve off the poppet valve's lower seat is the beginning of the fuel injection process.

POPPET VALVE

The poppet valve has two positions which are opened and closed. In the closed position, the poppet is held on the lower poppet seat by a spring. The closed lower poppet seat prevents high pressure actuation oil from entering the unit injector. The open upper poppet seat vents oil in the cavity that is above the intensifier piston to the atmosphere. The oil is vented to the atmosphere through the upper portion of the unit injector. In the open position, the solenoid is energized and the poppet valve is lifted off the poppet valve's lower seat. When the poppet valve is lifted off the poppet valve's lower seat, the lower poppet seat opens allowing high pressure actuation oil to enter the unit injector. When the high pressure actuation oil enters the unit injector, the high pressure actuation oil pushes on the top of intensifier piston. The upper poppet seat of poppet seat of poppet valve blocks the path to the drain. Blocking the path to the drain prevents the leakage of high pressure actuation oil from the unit injector.

INTENSIFIER PISTON

The surface area of intensifier piston is a bit over six times larger than the surface area of plunger. This larger surface area provides a multiplication of force. This multiplication of force allows 24 MPa (3,500 psi) of actuation oil to produce 162 MPa (23,500 psi) of fuel injection pressure. When poppet valve moves away from lower poppet seat high pressure actuation oil enters the unit injector, the high pressure actuation oil pushes on the top of intensifier piston. Pressure rises on top of the intensifier piston and the pressure pushes down on intensifier piston and plunger. The downward movement of the plunger pressurizes the fuel in plunger cavity. The pressurized fuel in the plunger cavity causes nozzle assembly to open. When the nozzle assembly opens, the fuel delivery into the combustion chamber begins. A large O-ring around the intensifier piston separates the oil above the intensifier piston from the fuel below the intensifier piston.

BARREL

The barrel is the cylinder that holds plunger. The plunger moves inside the barrel. The plunger and barrel together act as a pump. Both the plunger and the barrel are precision components that have a working clearance of only 0.0025 mm (.00010 inch). These tight clearances are required in order to produce injection pressures over 162 MPa (23,500

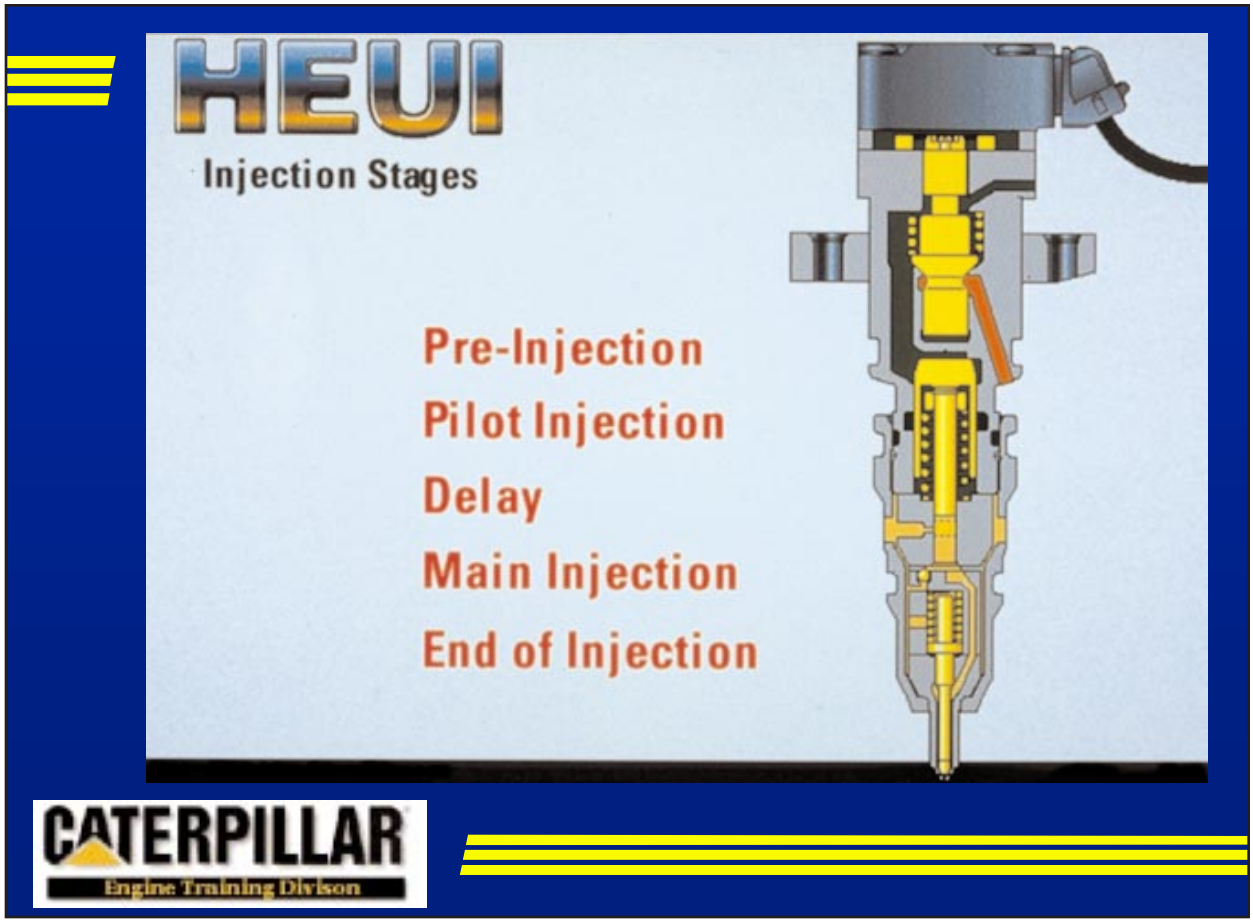
psi) without excessive leakage.

Note: A small amount of leakage is required in order to lubricate the plunger which prevents wear.

The barrel also contains the PRIME spill port. The PRIME spill port is a small hole with a high precision tolerance. The PRIME spill port is machined through the side of barrel into plunger. This port momentarily vents fuel injection pressure during the downward stroke of the plunger

NOZZLE ASSEMBLY

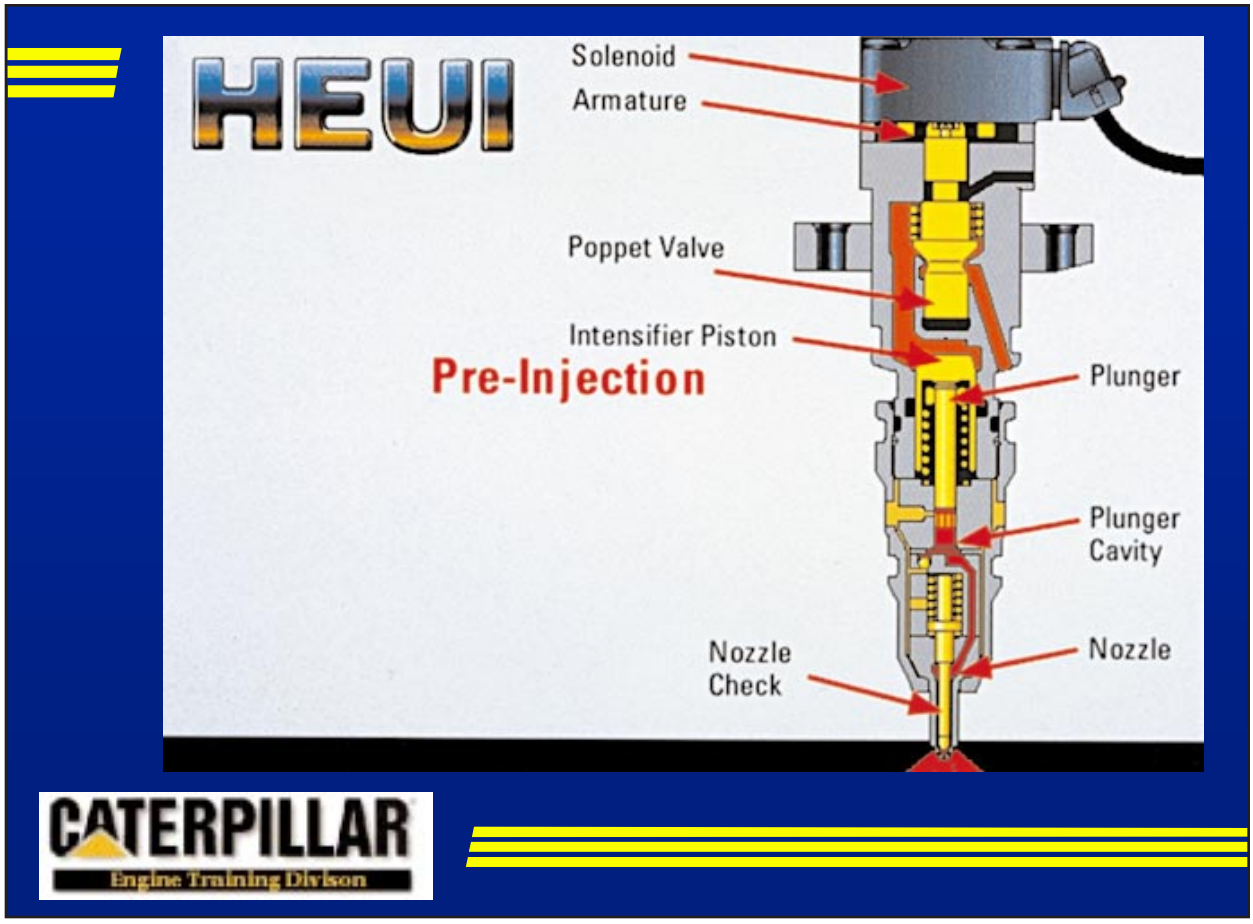
The nozzle assembly is similar to all other unit injector's nozzle assemblies. Fuel that has been pressurized to the injection pressure flows from the plunger cavity through a passage in the nozzle to the nozzle tip. Fuel flow out of the tip is stopped by check, which covers the tip orifice holes in the end of the tip. The force of a spring holds the check down in the closed position. This prevents the leakage of fuel out of combustion gas into the unit injector when the cylinder fires.



SLIDE 152

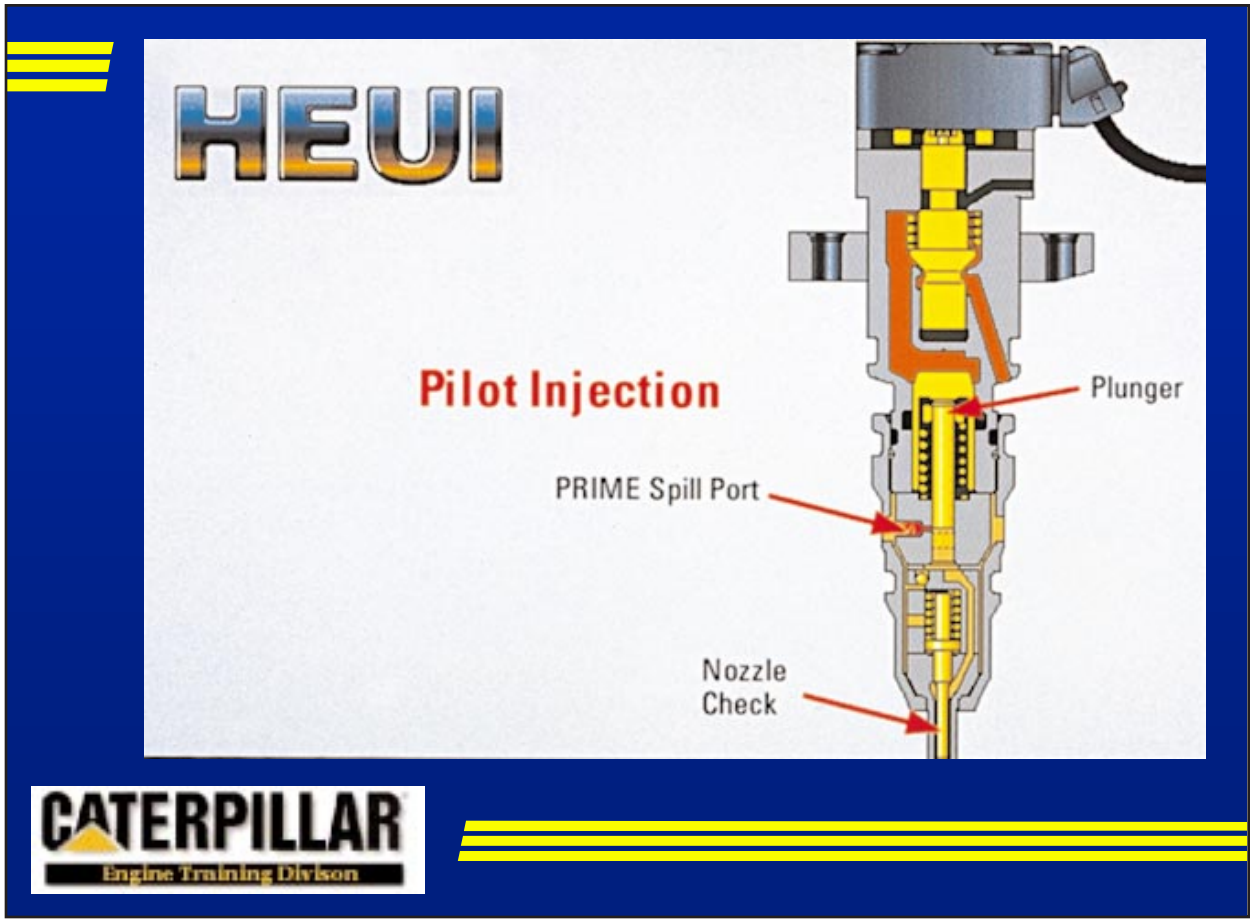
There are five stages of injection with the HEUI:

- Pre-Injection
- Pilot Injection
- Delay
- Main Injection
- End of Injection



SLIDE 153

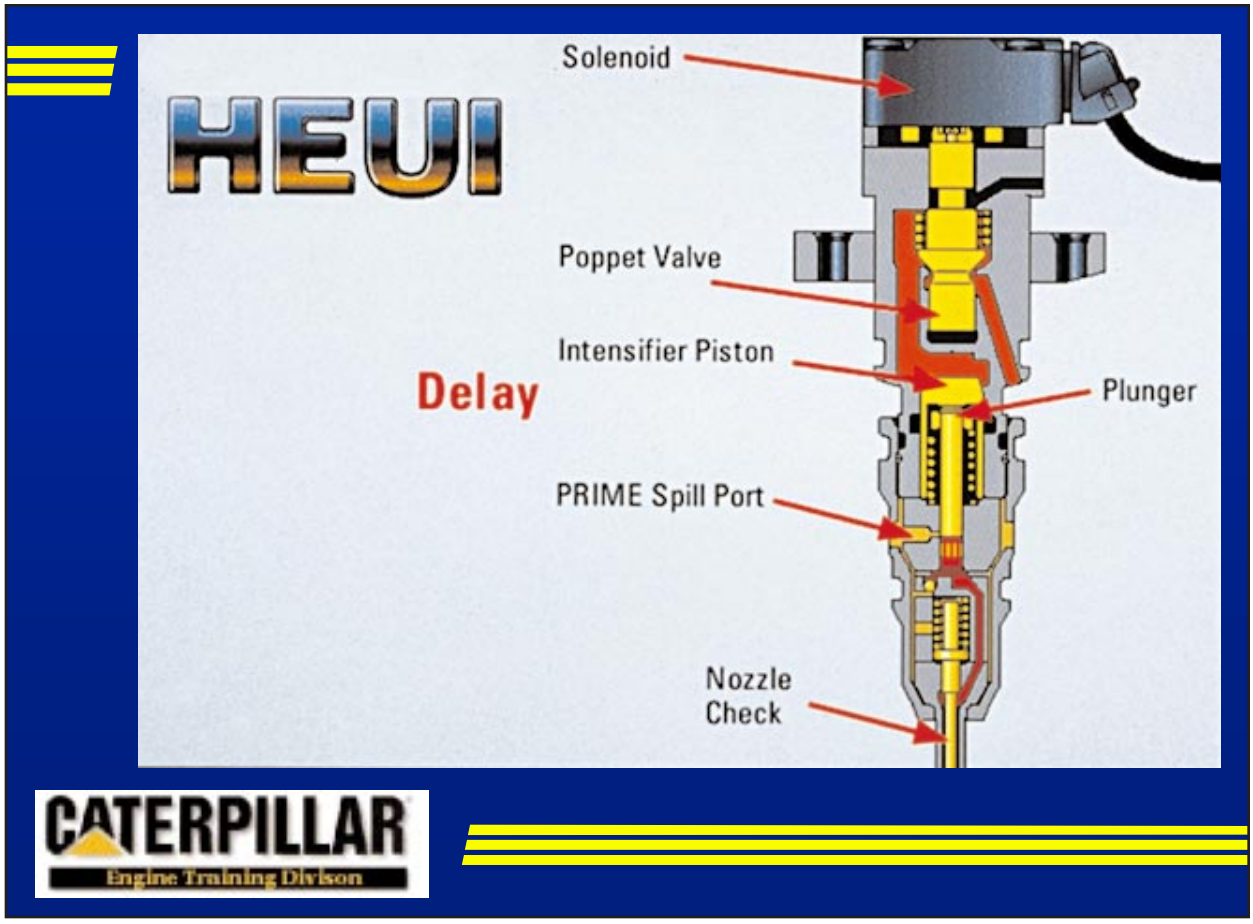
During pre-injection, all internal components have returned to their spring loaded (non-actuated) position. The solenoid is not energized and the and the lower poppet seat is closed. When the lower poppet seat is closed, the lower poppet seat blocks high pressure actuation oil from entering the unit injector. The plunger and the intensifier piston are at the top of their bores and the plunger cavity is full of fuel. Fuel pressure in the plunger cavity is equal to the fuel transfer pressure. The fuel transfer pressure is approximately 450 kPa (65 psi).



SLIDE 154

Pilot Injection (PRIME)

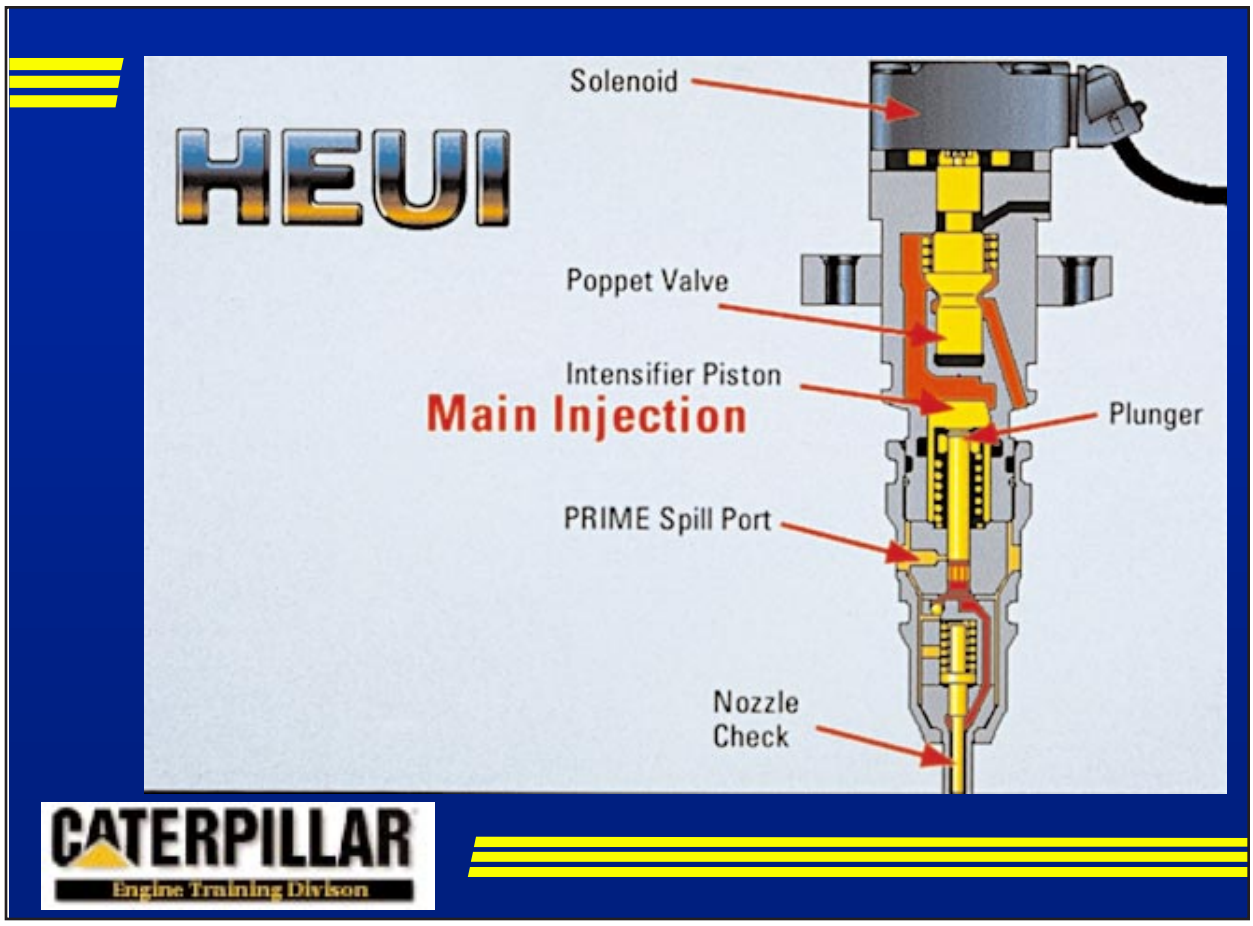
The 3126B/E diesel engine fuel system has a unique feature that is called PRIME. Pre-Injection Metering (PRIME) is a feature that offers a significant benefit in lower emissions. Also, PRIME offers a significant benefit in reducing combustion noise. While other fuel systems deliver a single large quantity of fuel into the combustion chamber, PRIME injectors break the delivery into two separate quantities. The first quantity is a small pilot injection which is followed by a short delay. Then, the injector delivers a large main injection. The pilot injection is intended to establish a flame front. The pilot injection will help the larger main injection burn more completely and in a more controlled fashion.



SLIDE 155

Delay

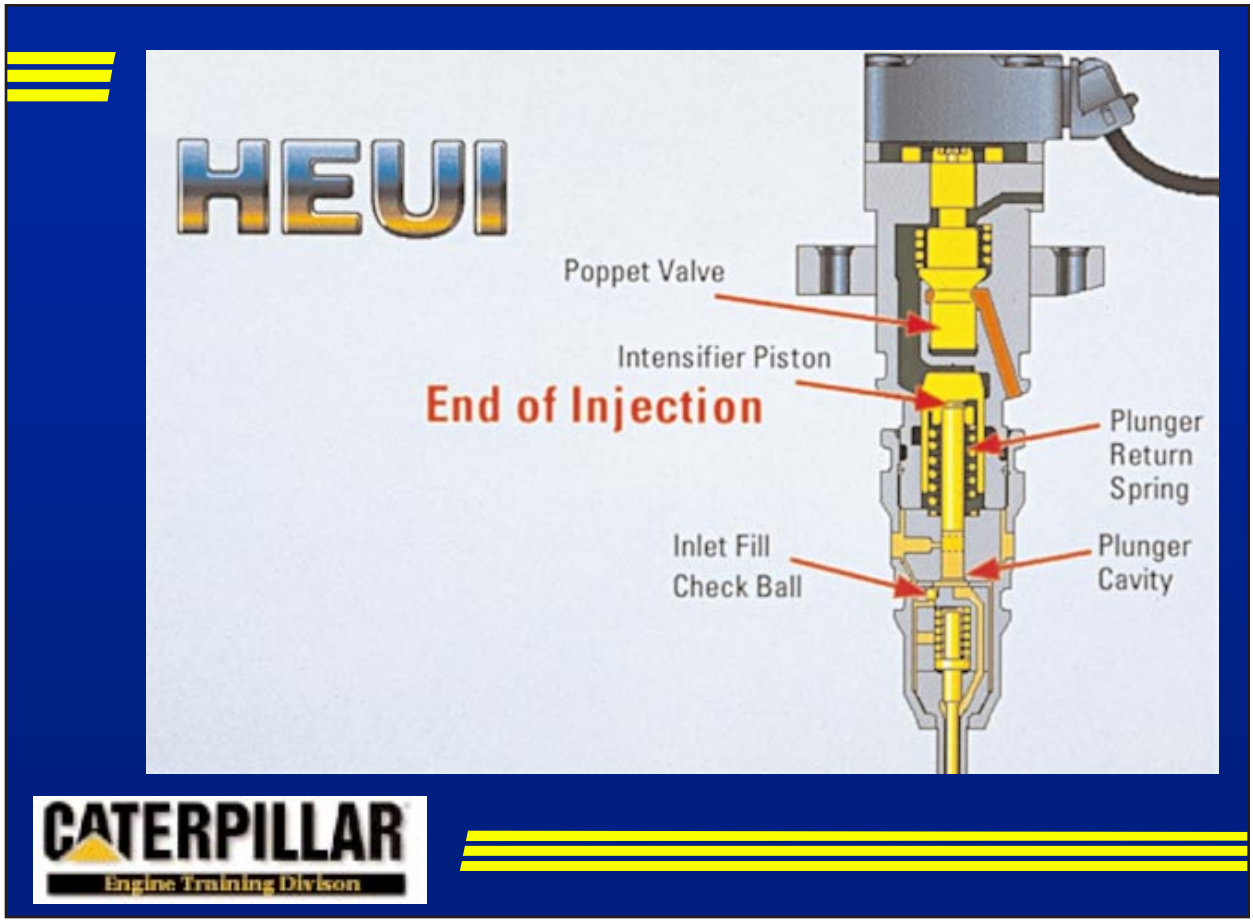
The PRIME feature produces a small pilot injection that is followed by a brief delay. The brief delay gives the pilot injection the time that is required to start burning. The main injection follows the pilot injection and the main injection is delivered into the flame front that was established by the pilot injection. The main injection is immediately ignited. The main injection burns smoothly and completely. This complete combustion significantly reduces particulate emission (soot) and NO_x. This complete combustion also reduces combustion noise from the engine up to 50 percent, therefore noticeably quieter engine operation.



SLIDE 156

Main Injection

While the solenoid is energized, the poppet valve remains open. While the poppet valve is open, high pressure oil flows into the area above the intensifier piston. The flow of the high pressure oil pushes downward on the intensifier piston and the plunger. The injection pressure fluctuates between 34 MPa (5000 psi) and 162 MPa (23500 psi). The injection pressure depends on the engine's requirements. Injection continues until either the solenoid is de-energized or the intensifier piston hits the bottom of its bore. When the solenoid is de-energized, the poppet spring is allowed to close the poppet valve. When the poppet valve closes, the high pressure oil supply is shut off.



SLIDE 157

End of Injection

The end of the injection cycle begins when the ECM stops the current to the unit injector solenoid. The magnetic field of the solenoid breaks down and the magnetic field is unable to overcome the spring force of the poppet. The poppet returns to the lower poppet seat which closes the poppet valve. When the poppet valve closes, high pressure oil is stopped from entering the unit injector. As the lower poppet seat closes, the upper poppet seat opens to the drain. When the upper poppet seat opens to the drain, the actuation pressure of the oil drops off.

Fuel injection pressure under the plunger and the plunger return spring exert an upward force on the plunger and the intensifier piston. As the pressure of the actuation oil above the intensifier piston drops off, the downward force on the intensifier piston drops off. The upward force of the fuel injection pressure under the plunger coupled with the plunger spring force suddenly becomes greater than the downward force on the

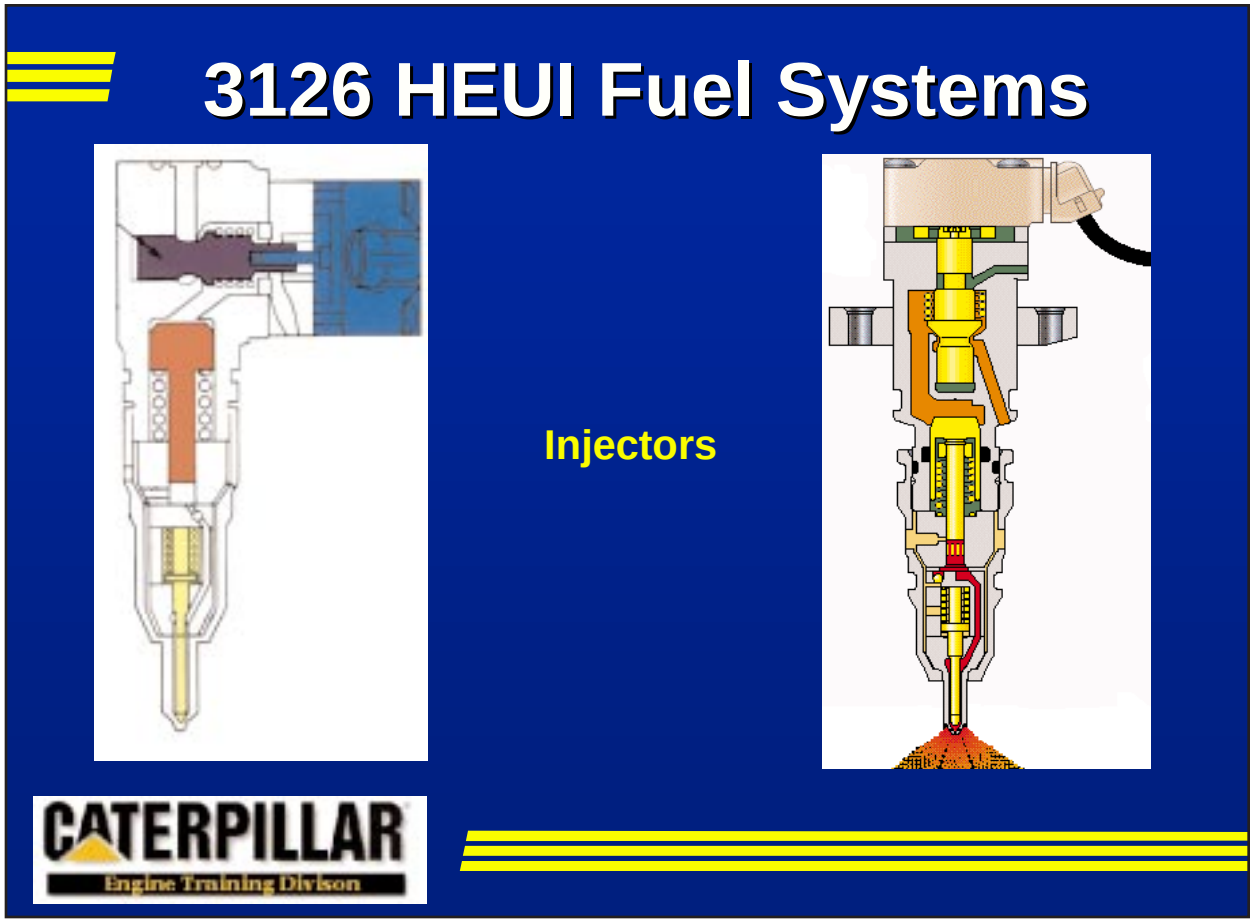
intensifier piston. The downward motion of the intensifier piston and the plunger stops.

The exhaust oil on top of the intensifier piston can flow to the drain through the open upper poppet seat. Then, the oil flows through a vent hole to the rocker arm compartment under the valve cover.

When the downward travel of the plunger stops, fuel flow also stops. While the check is still open, the remaining fuel pressure pushes a small amount of fuel out of the orifice holes. This causes a large pressure drop which lowers injection pressure below Valve Closing Pressure (VCP). Spring tension on the check now reseats the check into the tip and injection stops.

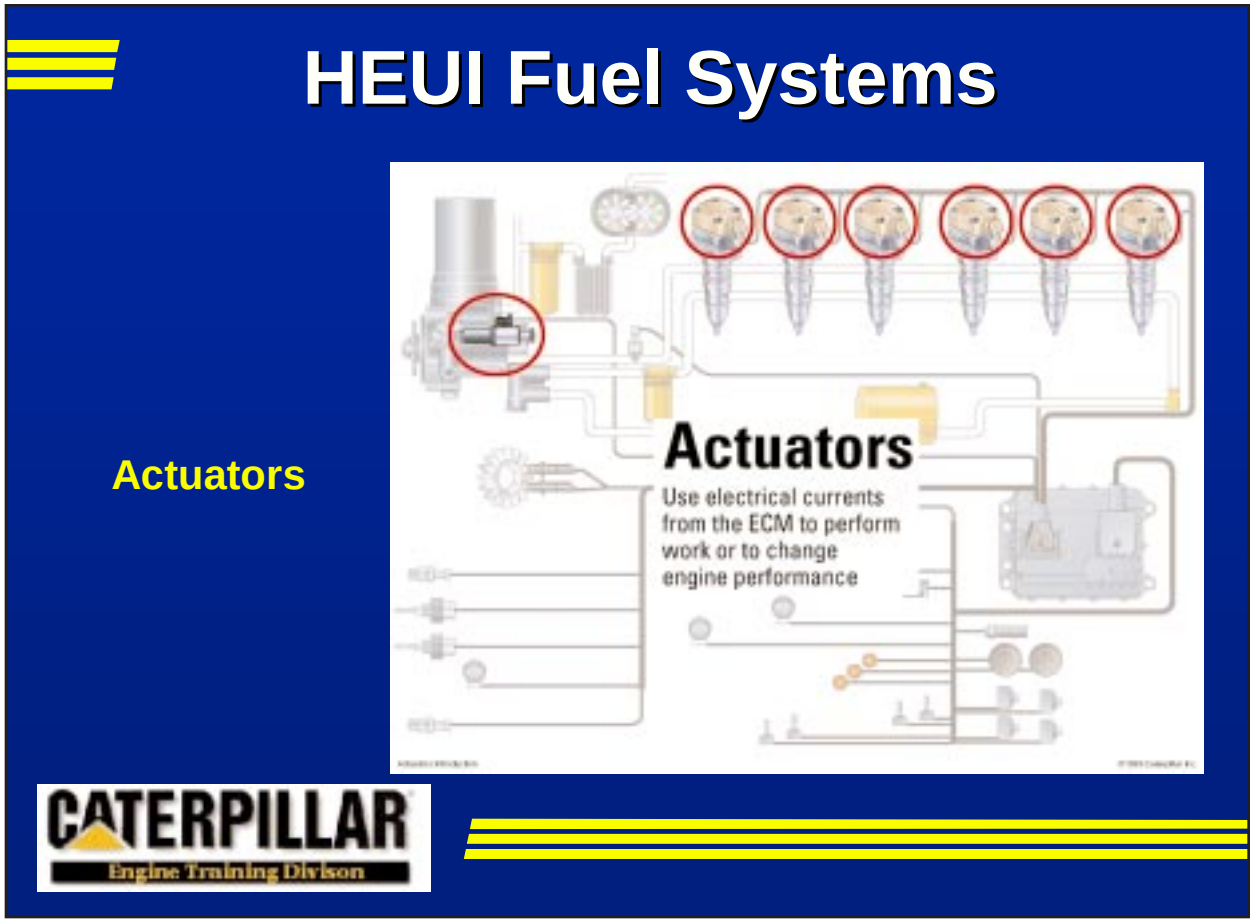
When the check closes, injection stops. When injection stops, the fill cycle starts. The area above the intensifier piston cavity is open to atmospheric pressure through the upper poppet seat. Pressure drops very rapidly in the cavity above the intensifier piston to near zero. The return spring of the plunger pushes up on the intensifier piston. As the plunger and the intensifier piston move upward, oil is forced around the upper poppet seat. After the oil is forced around the upper poppet seat, the oil is forced out of a vent hole.

As the plunger rises, pressure in the plunger cavity also drops to near zero. The fuel supply pressure is 450 kPa (65 psi). Fuel supply pressure unseats the plunger fill check in order to fill the plunger cavity with fuel. When the intensifier piston is pushed to the top of the bore, the fill cycle ends. When the fill cycle ends, the plunger cavity is full and the inlet fill check ball is reseated. Pressure above the intensifier piston and the poppet chamber is zero. The fuel injection cycle is complete and the unit injector is ready to begin again. The unit injector is now back in the pre-injection cycle.



SLIDE 158

Although the 3126B/E injector looks different than the 3126 injector, the function is very similar. The prime differences their function and operation are the orientation of the poppet valve and the addition pilot injection on the 3126B/E.



SLIDE 159

Actuators

All of the functions of the fuel system are controlled by the ECM using the infomation it gathers from the various engine sensors. This data is used to control engine actuators.

The first actuator, the IAPCV controls injection pressure by controlling the pressure of the HEUI oils supply.

The second actuator, the solenoid on the HEUI injector, controls timing and duration.

SMALL ENGINE FUEL SYSTEMS

Lesson Plan 16 - Quiz 3

Objectives:

- The student will take a quiz to review and test the previous day's material. A minimum of 70% accuracy is considered acceptable.

Literature:

Quiz 3 Copy

Hardware Needed:

None

Time Required:

0.5 hours

Tasks Required by Instructor to Meet Objectives:

1. Ask students for questions regarding material covered the previous day.
2. Answer all questions ;using reference material. Be sure the student follow along in their reference material while the question is answered.
3. Administer Quiz 3.
4. Review Quiz 3, again using reference material to answer questions.

SMALL ENGINE FUEL SYSTEMS

Lesson Plan 16 - Quiz 3

Select the best answer - If the answer is false on a true/false question, corredt the question to make it true.

1. The available operating pressure range for the hydraulic oil pressure in a 3116 HEUI engine is:

   A. 625 to3335 psi

   B. 725 to 3000 psi

   C. 725 to 3335 psi

   D. 600 to 3335 psi

2. The fuel ratio control on a Type III 3116 governor is not in a restrictive position during cranking.

   A. True

   B. False

3. A 3126B HEUI engine will not start until the injection actuation pressure has reached:

   A. 735 psi

   B. 780 psi

   C. 870 psi

   D. 3000 psi

4. The horsepower tolerance of a new engine at governed speed is:

   A. +/- 5%

   B. + 3% / - 5%

   C. + 6% / - 7%

   D. +/- 3%

5. The difference between governed rpm and high idle rpm is called:

   A. Governor overrun

   B. Droop

   C. A and B

   D. None of the above

6. BSFC (Brake Specific Fuel Consumption) is the amount of fuel consumed to produce one horsepower for one minute.

   A. True

   B. False

7. Which of the following is true concerning a 3126B/E truck engine?

   A. The injector uses a jumper tube

   B. The injector has pilot injection

   C. The injector has up to 30,000 psi injection pressure

   D. A and B

   E. B and C

   F. A and C

   G. All the above

8. Whic of the following are standard conditions for a 3126 JWAC marine engine?

   A. 35 API @ 60 degrees F

   B. 110 degrees F intake manifold temperature

   C. 30.5” Hg barometer

   D. A and B

   E. A and C

   F. B and C

   G. All the above

9. In most cases, using the 173-1530 injector seating tool group eliminates the need for using a roll burnisher when changing injector sleeves.

   A. True

   B. False

10. The 173-1530 injector seating tool group is used on all the following engines except:

    A. 3114 and 3116 MUI

    B. 3116 HEUI

    C. 3126 HEUI

    D. 3126B/E HEUI

SMALL ENGINE FUEL SYSTEMS

Lesson Plan 16 - Quiz 3

Select the best answer - If the answer is false on a true/false question, corredt the question to make it true.

1. The available operating pressure range for the hydraulic oil pressure in a 3116 HEUI engine is: C

   A. 625 to3335 psi

   B. 725 to 3000 psi

   C. 725 to 3335 psi

   D. 600 to 3335 psi

2. The fuel ratio control on a Type III 3116 governor is not in a restrictive position during cranking. B - This type takes boost to move it out of restrictriction

   A. True

   B. False

3. A 3126B HEUI engine will not start until the injection actuation pressure has reached: C

   A. 735 psi

   B. 780 psi

   C. 870 psi

   D. 3000 psi

4. The horsepower tolerance of a new engine at governed speed is: D

   A. +/- 5%

   B. + 3% / - 5%

   C. + 6% / - 7%

   D. +/- 3%

5. The difference between governed rpm and high idle rpm is called: C

   A. Governor overrun

   B. Droop

   C. A and B

   D. None of the above

6. BSFC (Brake Specific Fuel Consumption) is the amount of fuel consumed to produce one horsepower for one minute. B - one hour

   A. True

   B. False

7. Which of the following is true concerning a 3126B/E truck engine? B

   A. The injector uses a jumper tube

   B. The injector has pilot injection

   C. The injector has up to 30,000 psi injection pressure

   D. A and B

   E. B and C

   F. A and C

   G. All the above

8. Whic of the following are standard conditions for a 3126 JWAC marine engine? E

   A. 35 API @ 60 degrees F

   B. 110 degrees F intake manifold temperature

   C. 30.5” Hg barometer

   D. A and B

   E. A and C

   F. B and C

   G. All the above

9. In most cases, using the 173-1530 injector seating tool group eliminates the need for using a roll burnisher when changing injector sleeves. B - reamer

   A. True

   B. False

10. The 173-1530 injector seating tool group is used on all the following engines except: D

    A. 3114 and 3116 MUI

    B. 3116 HEUI

    C. 3126 HEUI

    D. 3126B/E HEUI

Small Engine Fuel Systems

Lesson Plan 17 - Introduction to C-9 HEUI Fuel Systems

Objectives:

- The student will be able to explain the operation, disassembly, assembly, setting procedure and testing of the C-9 HEUI fuel system with 70% accuracy on a written test.

Literature Needed:

C-9 HEUI Fuel System Slide Script	Copy
HEUI HI300B Fuel System	RENR1392

Hardware Needed:

Slide Projector

Screen

C-9 HEUI Fuel System Slides

HEUI HI300B CD

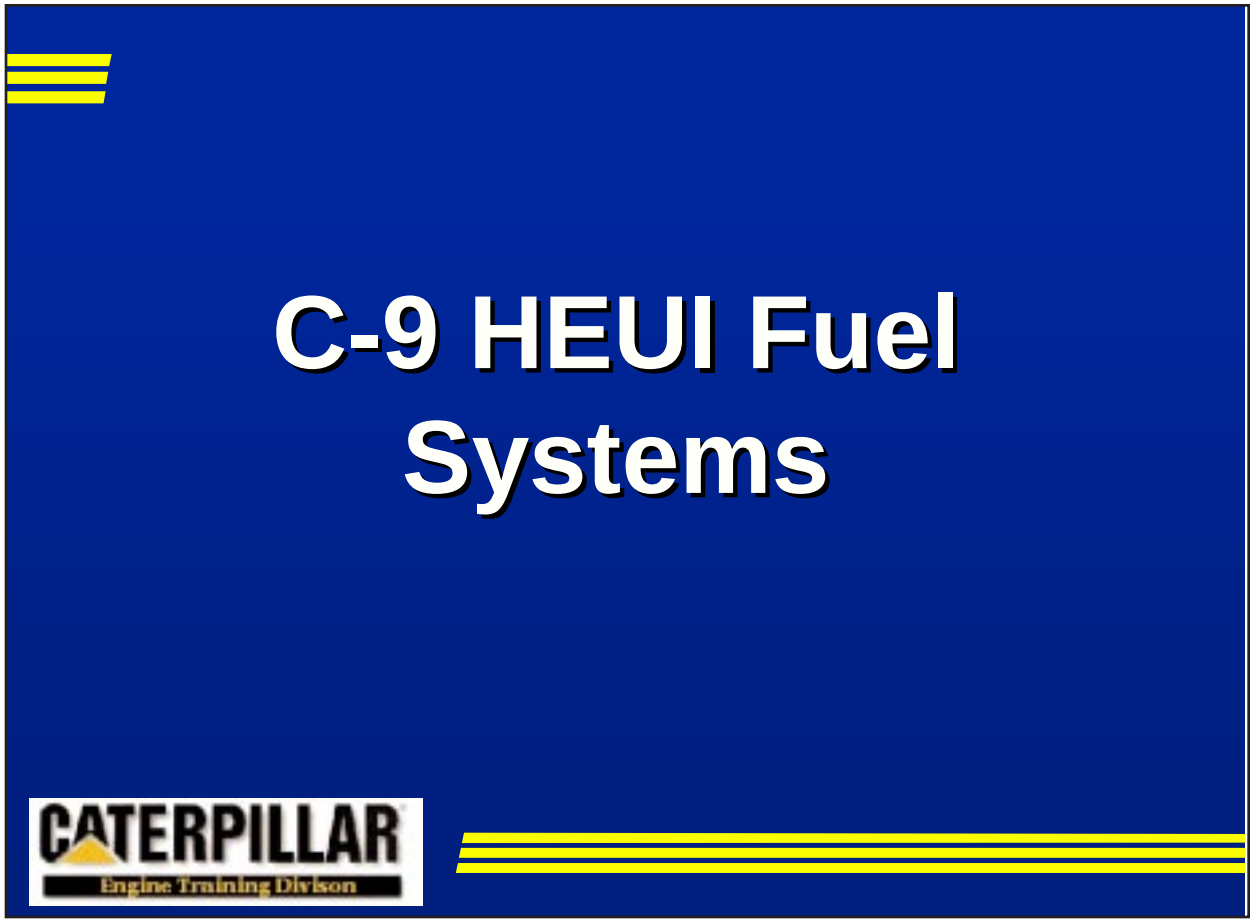
PC Computer

Time Required:

1.75 Hour

Tasks Required by Instructor to Meet Objectives:

1. Review the slides and emphasize the following points:
   A. Fuel system component placement
   B. Priming pump and filter
   C. HEP
   D. Transfer pump
2. Using the HI300B CD explain the operation of the HEUI B injector and HEP.

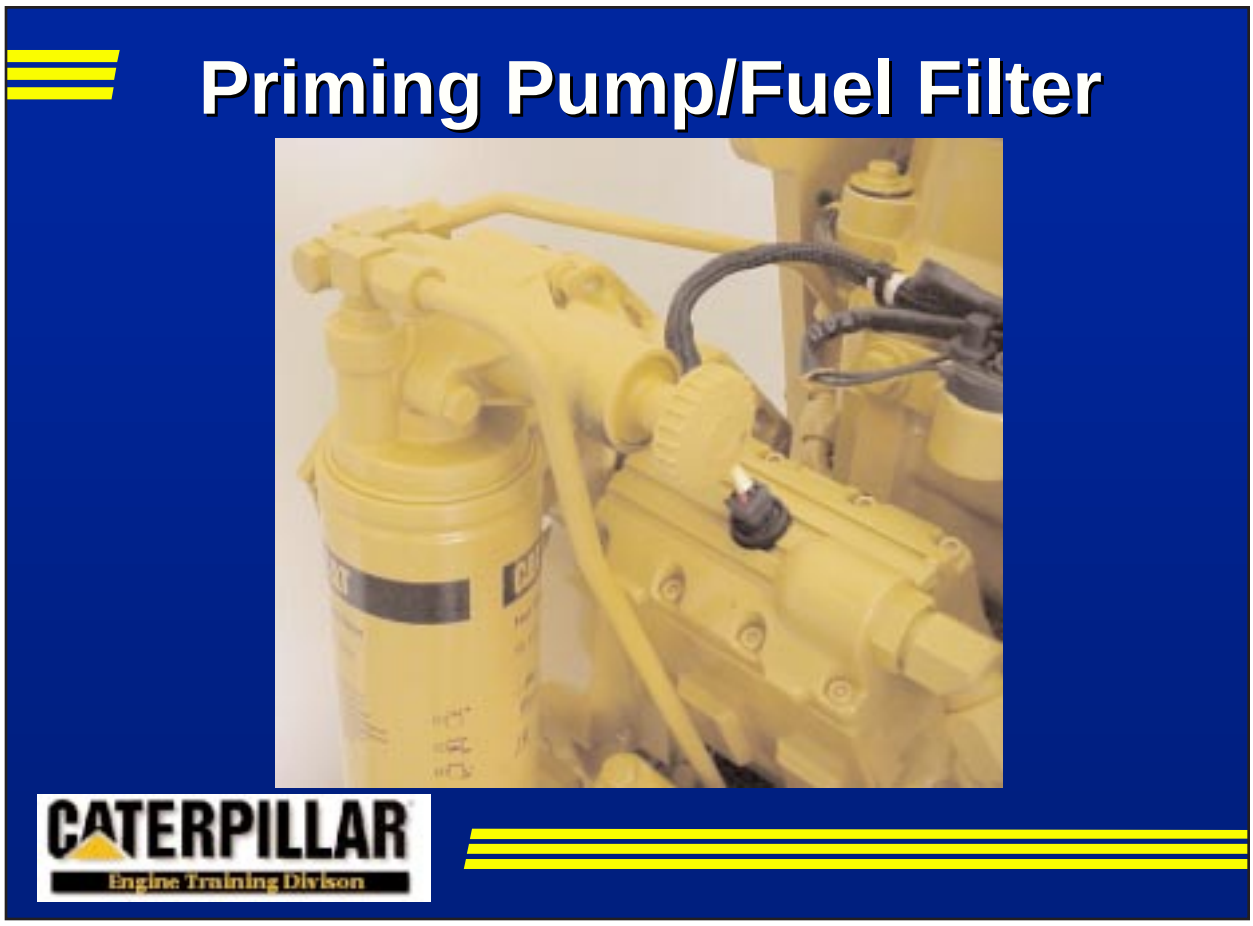


SLIDE 160

The next topic will be the C-9 HEUI fuel system. We will build on what we have already learned and discuss the new features of this system.

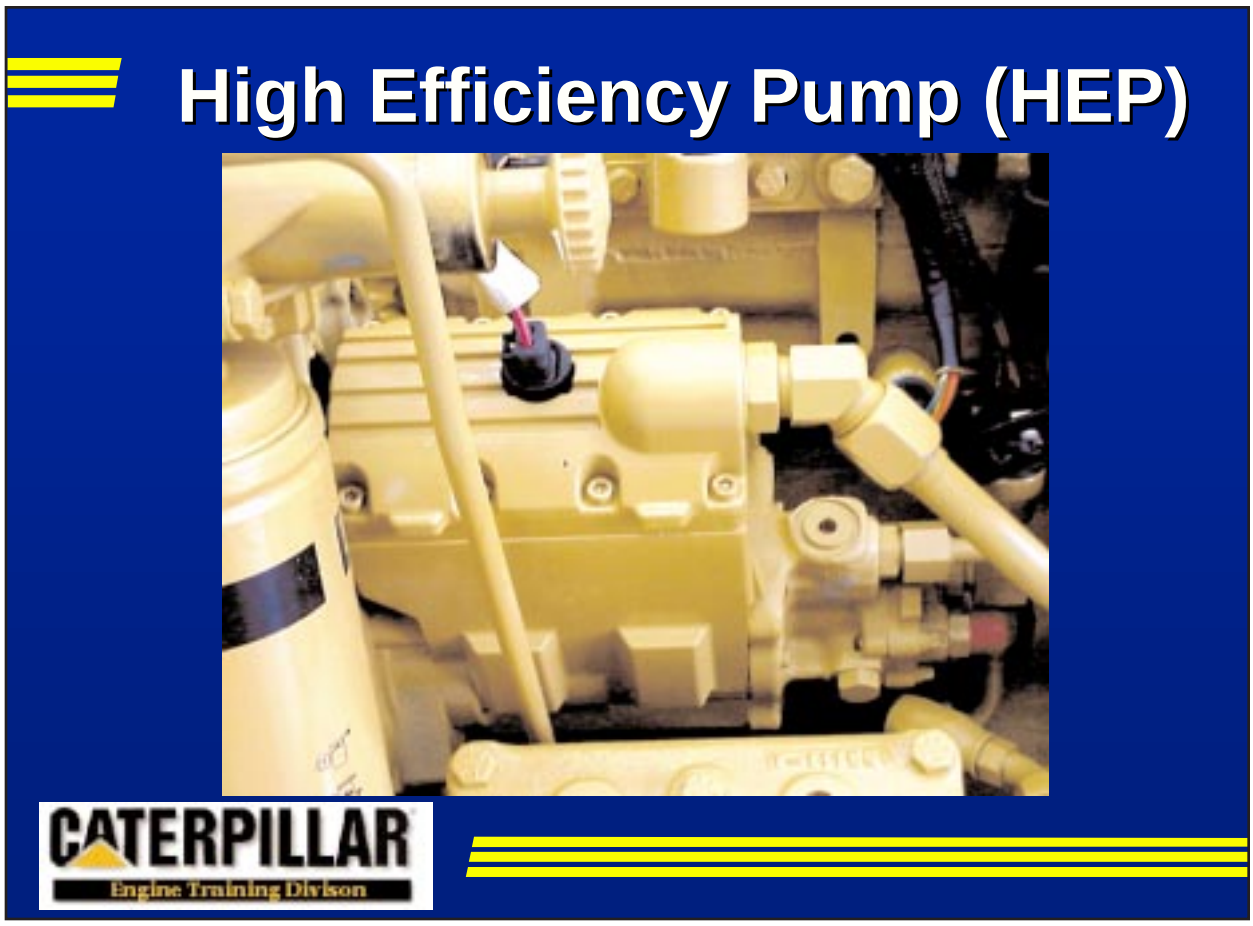
SLIDE 161

Most of the fuel system components are located on the left side of the engine. To the rear left side the ECM can be seen with its wiring harness. Now let's look at the other components.



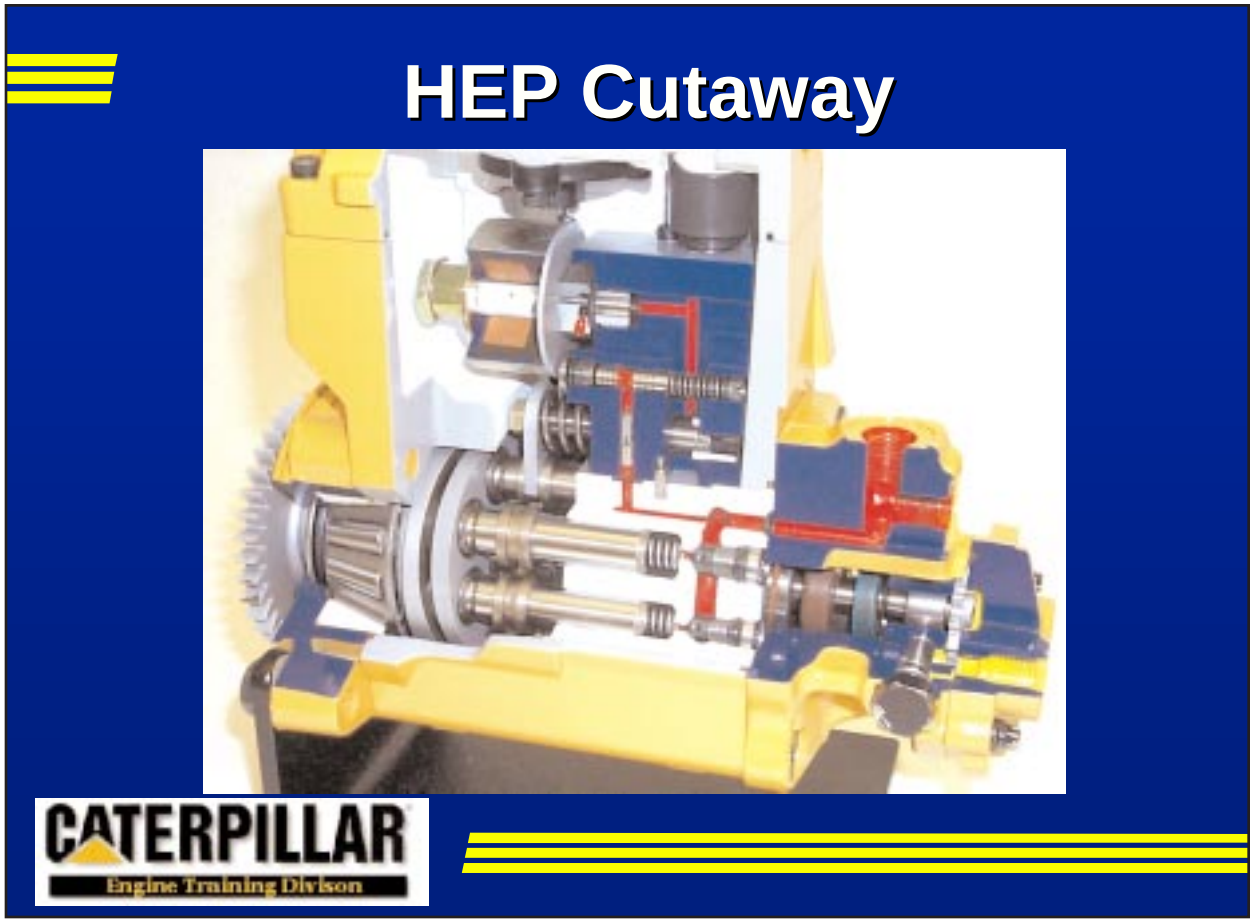
SLIDE 162

The fuel priming pump and filter base are located at the right front of the engine.



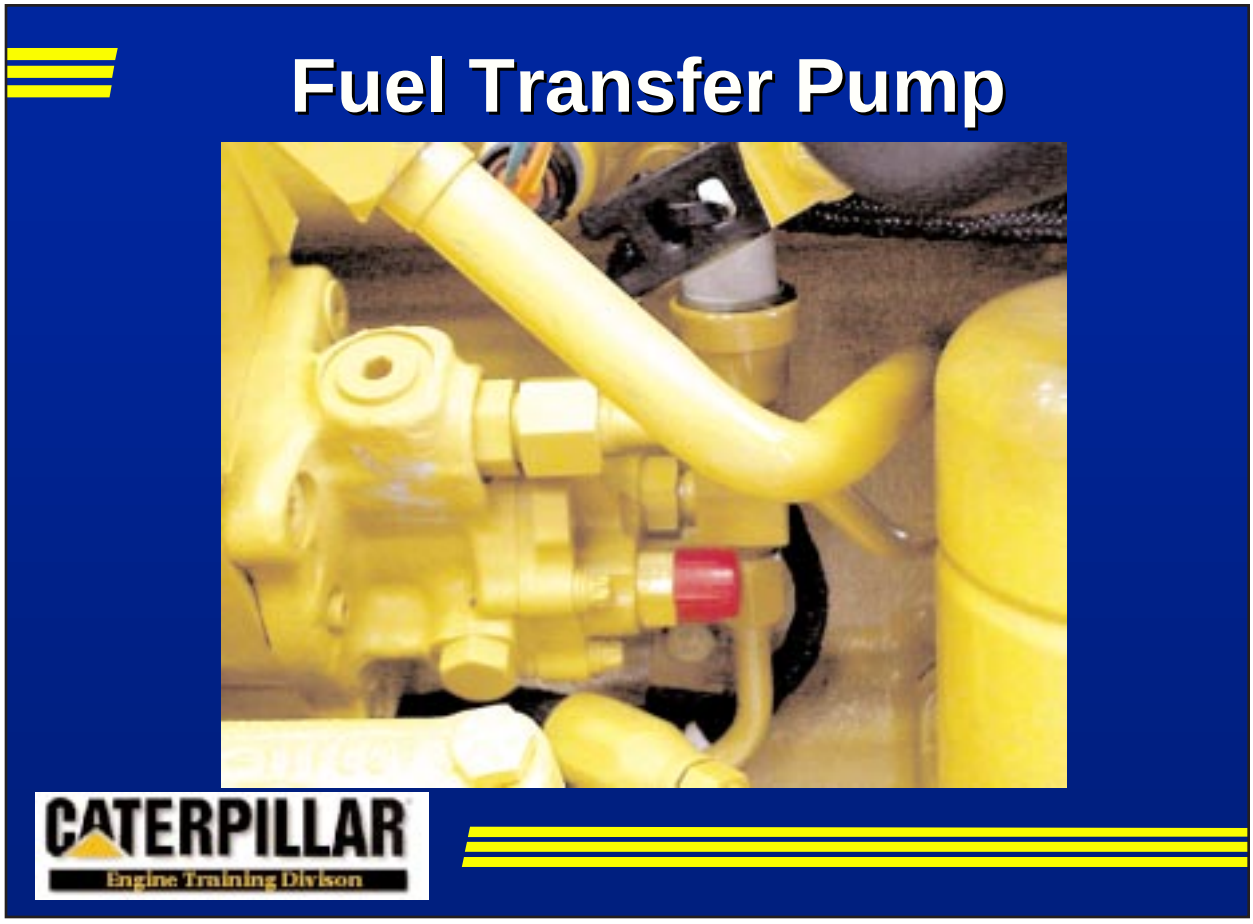
SLIDE 163

With the introduction of the C-9 engine, a new style high pressure oil pump was released. It is refered to as HEP which stands for High Effciency Pump. The oil for the HEUI fuel system is pumped and regulated by this unit. Therefore the IAPCV has been eliminated.



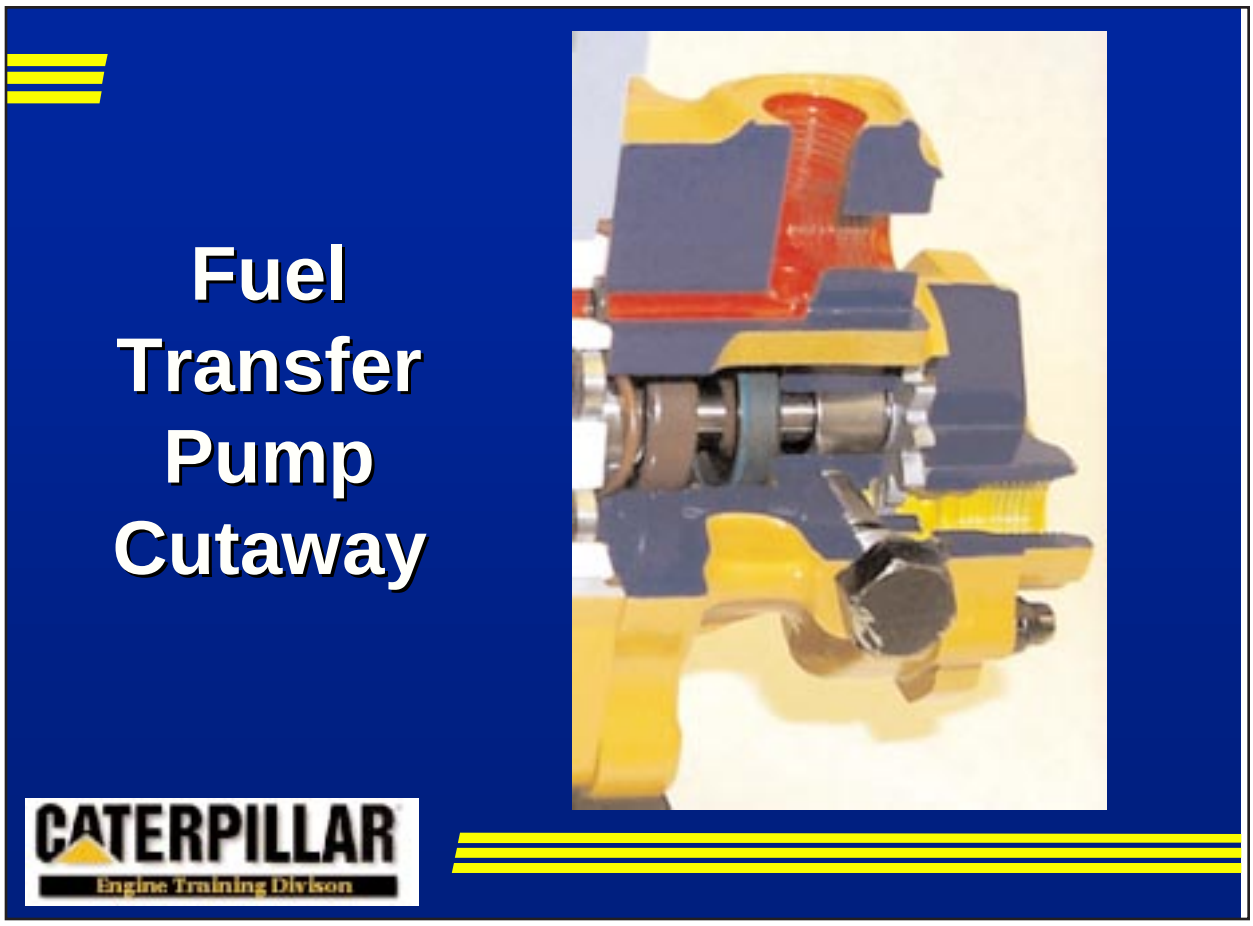
SLIDE 164

Here the internal parts of HEP are shown. This oil pump operates much like the Sleeve Metering Fuel System. A sleeve is used to provide the required flow and pressure. This is controlled by an internal valve much like the older IAPCV. Toward the back of the HEP, the gear type fuel transfer pump is found.



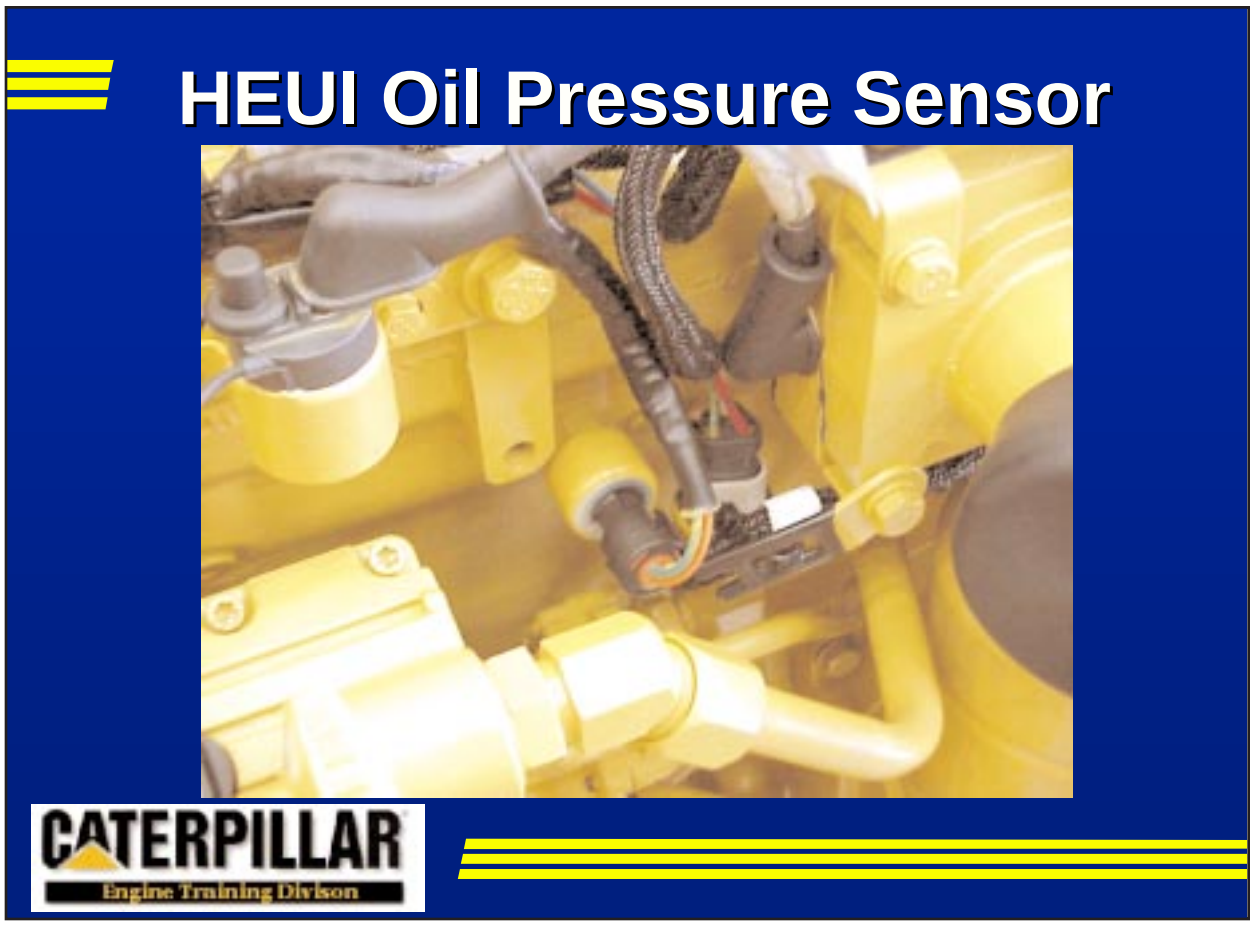
SLIDE 165

The fuel transfer pump is mounted on the rear of the HEP. It is driven by the HEP shaft.



SLIDE 166

Here is the cutaway of the gear type transfer pump with the relief valve. This is the only servicable part of HEP. Care should be taken when removing the transfer pump. A bolt is provided in the transfer pump kit to hold HEP together during disassembly and assembly of the transfer pump from and to HEP.



SLIDE 167

As in other HEUI systems, we need to know the actual pressure of the oil in the HEUI manifold. This is a direct controller of injection pressure and must be monitored by the ECM. If the pressure is not what the ECM desires, it will change its signal to HEP to change HEUI manifold pressure. This provides a closed loop system for HEUI oil pressure.

SLIDE 168

The C-9 has dual speed timing sensors like the 3126 models which work the same way.

SLIDE 169

Here we see the valve cover removed showing the rocker assemblies and the HEUI injectors. The C-9 injector has a different shape and a modified operation that we will discuss later.

SLIDE 170

Here we see the HEUI injector nestled between the valves. The two wire electrical connector is shown in the unlocked position making it ready to disconnect.

SLIDE 171

The connector has been removed. On the top, the injector the serial number can be found. To the right and left, the allen head hold down bolts and hold down clamp are shown.

SLIDE 172

The injector puller is shown installed in the above slide. A breaker bar is used as the pulling lever arm. Prying the injector up instead of using the tool could cause damage to the injector.

SMALL ENGINE FUEL SYSTEMS

Lesson Plan 18 - 3208 Fuel System Introduction

Objectives:

With at least 70% accuracy on a written test, the student will be able to identify and explain the function of the individual parts of the 3208 fuel pump and governor.

Literature Needed:

6V4141 Sleeve Calibration Tool	SMHS7835
5P6577 Fuel Setting Tool Group	SMHS7013

Hardware Needed:

Slide Projector

Screen

3208 Fuel System Slides

Time Required

1 Hour

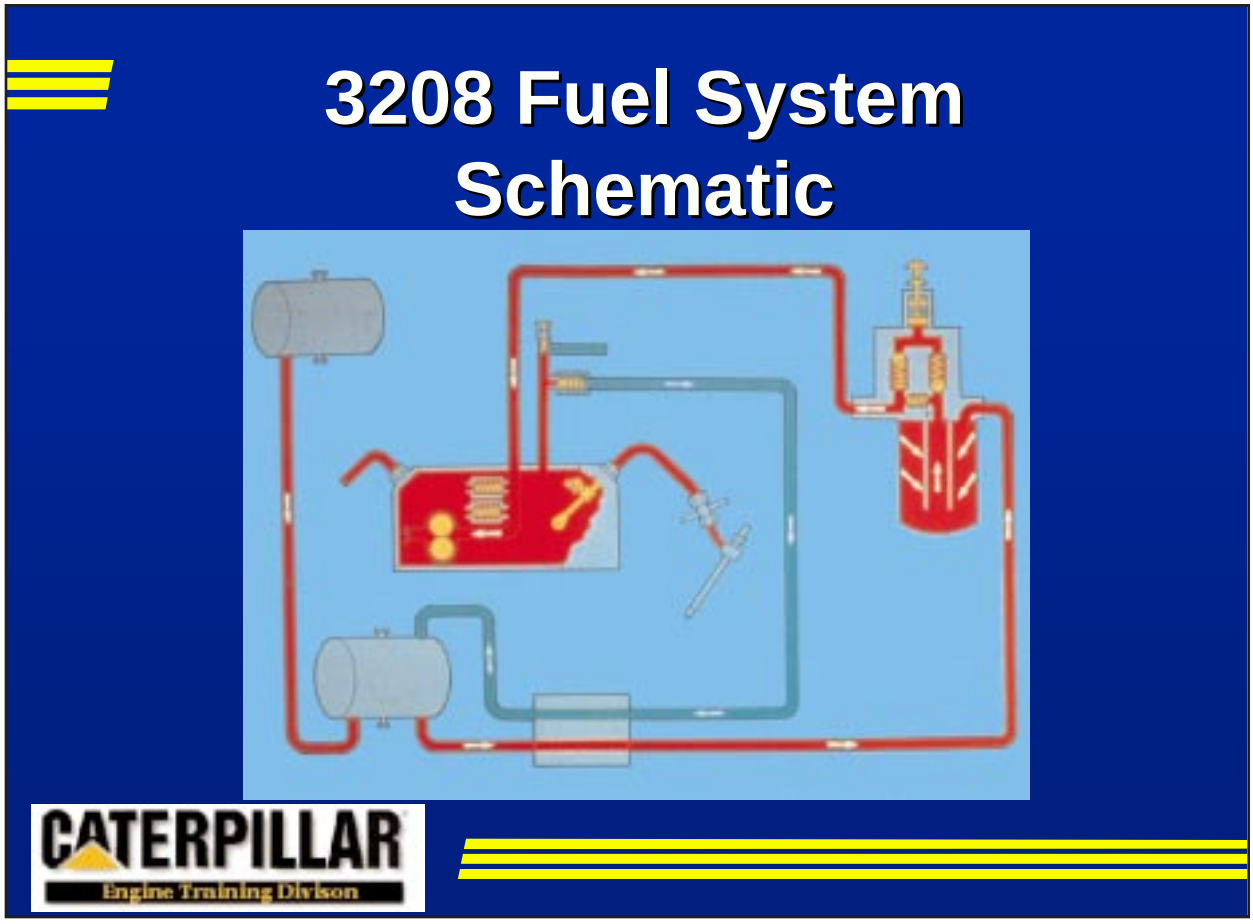
Tasks Required by Instructor to Meet Objectives

1. Review the slides and emphasize the following points:
   A. Fuel system consists and fuel flow path.
   B. Timing procedure
   C. Fuel pressure check
   D. Setpoint check
   E. Pump disassembly
   F. Fuel pump settings
   G. Governor operation
2. Ask if there are any questions and review any areas that might be unclear.

SLIDE 173

3208 Sleeve Metering Fuel System

The following presentation will discuss the Sleeve Metering fuel system used on the 3208 engine



SLIDE 174

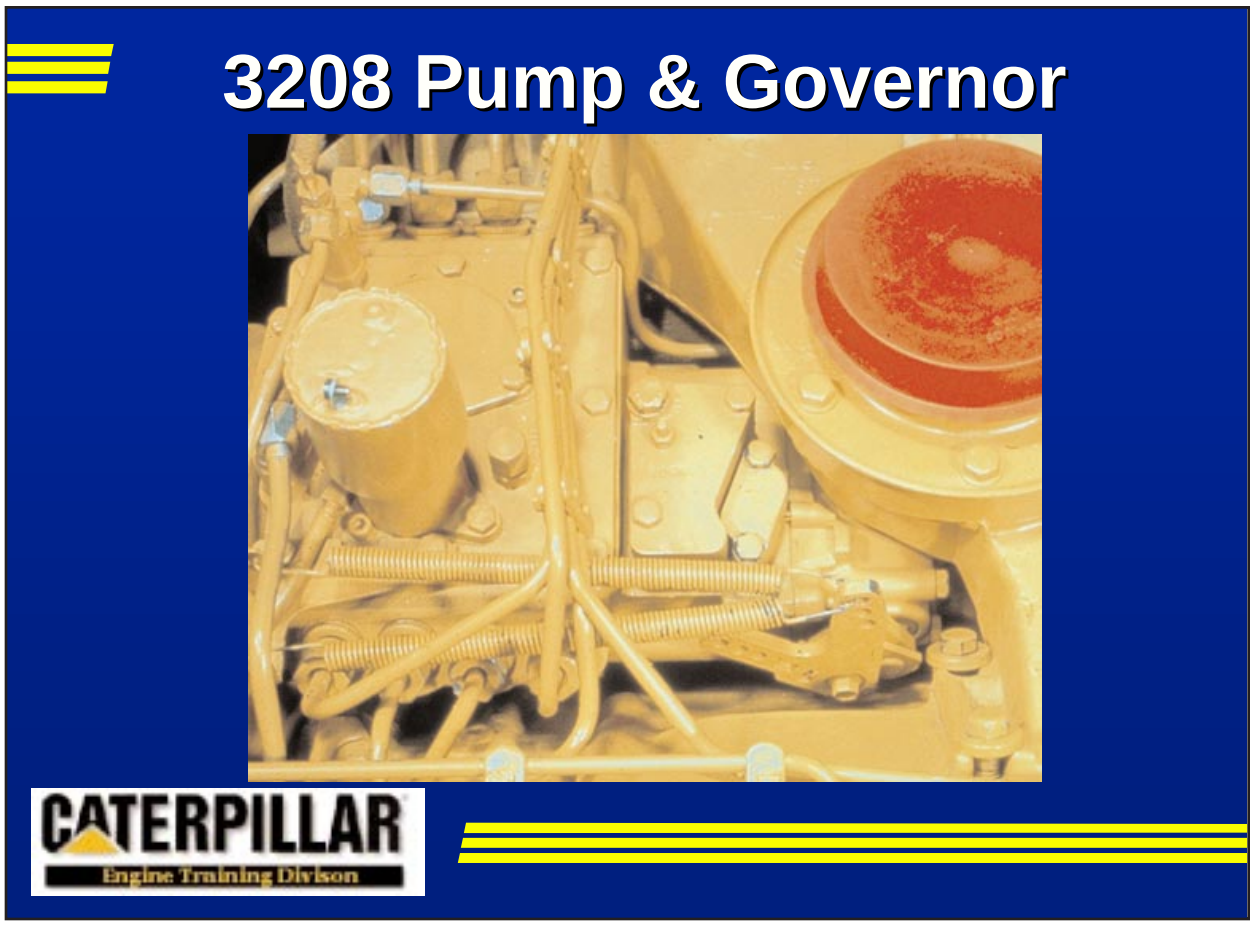
Fuel Flow

7000 Series Nozzle

Pencil Nozzle

This is a schematic of the 3208 fuel system. The 3208 engine has a sleeve metering type fuel injection pump. The engine could have either Caterpillar 7000 series nozzles or pencil-type nozzles. Earlier 3208 industrial engines had nozzles with a fuel return line. The components of the fuel system are:

- Fuel Tank/Tanks
- Fuel Junction Block
- Fuel Filter Base and Fuel Filter
- Priming Pump
- Fuel Injection Pump and Governor
- Fuel Lines
- Bulkhead Adapter
- Fuel Nozzles



SLIDE 175

Fuel Injection Pump

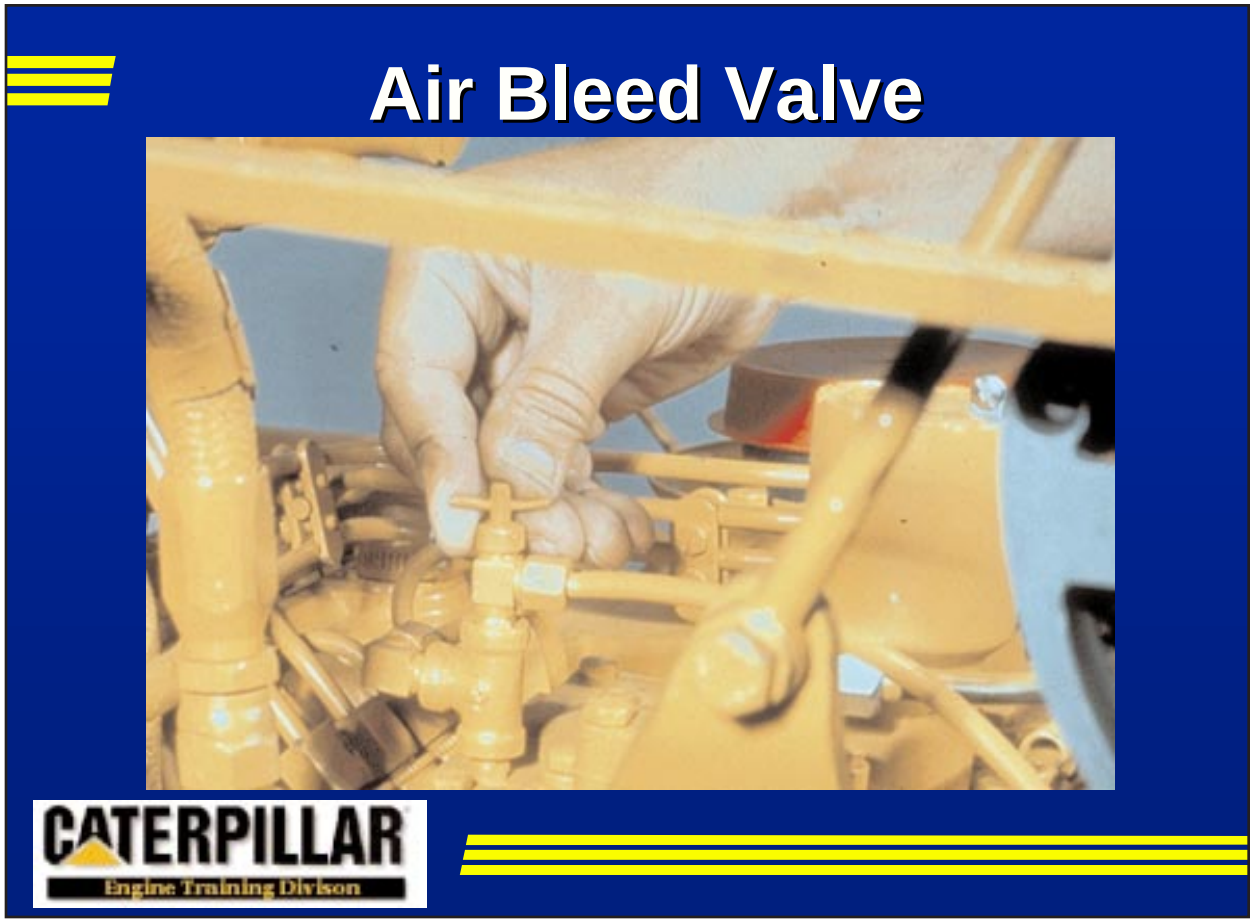
Transfer Pump

Governor Control Lever

Fuel Shutoff Solenoid

Air Bleed Valve

The fuel injection pump and governor are located in the forward section of the “V” of the engine. The gear-type fuel transfer pump is attached to the front of the pump housing. The governor is attached to the rear of the fuel pump housing. The governor control lever (throttle) is located on the left side of the governor housing. The fuel shutoff solenoid is on top of the fuel pump. This pump has an air bleed valve located at the front right coner of the fuel pump.

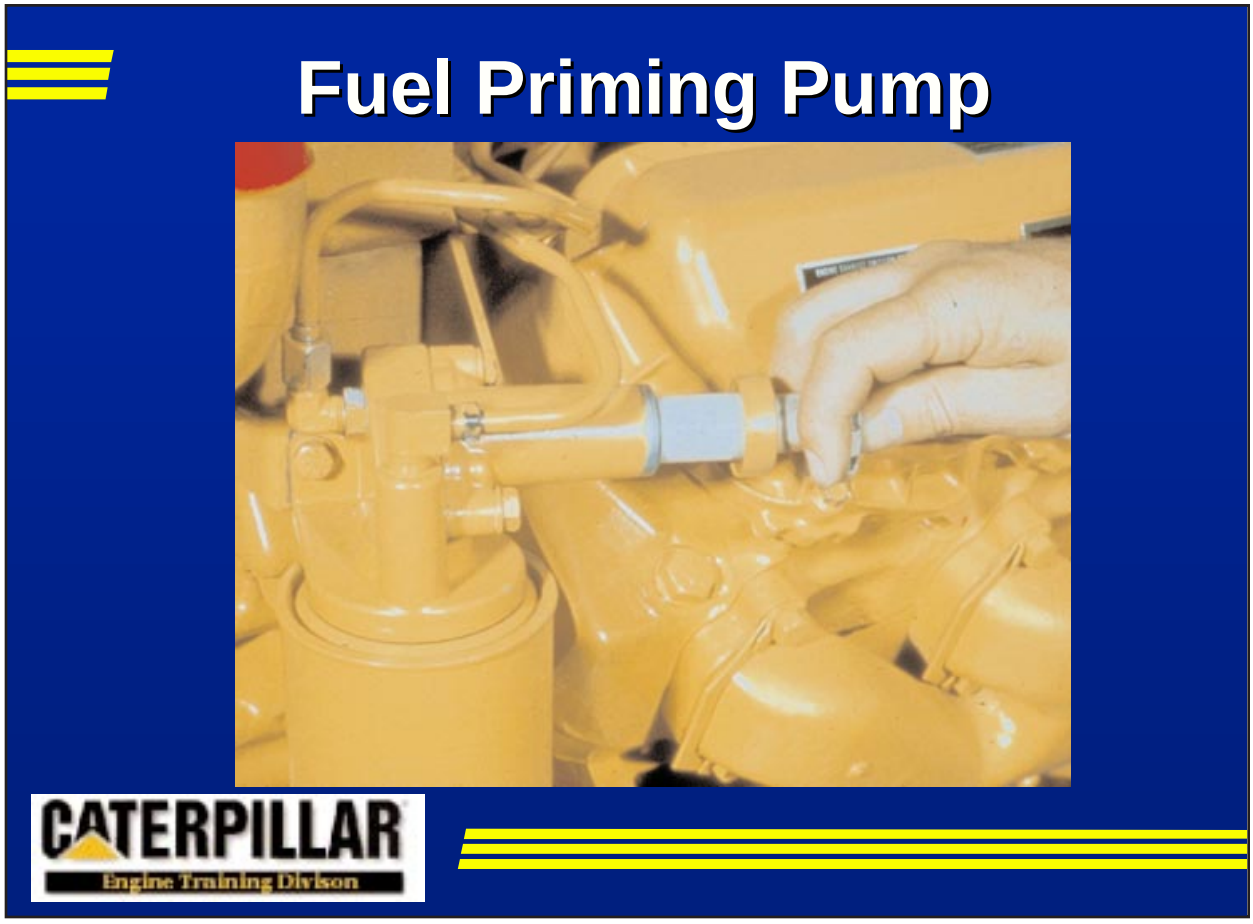


SLIDE 176

Air Bleed Valve

The air bleed valve is used to remove air from a new filter or, if necessary, to remove air from the system up to the injection pump housing.

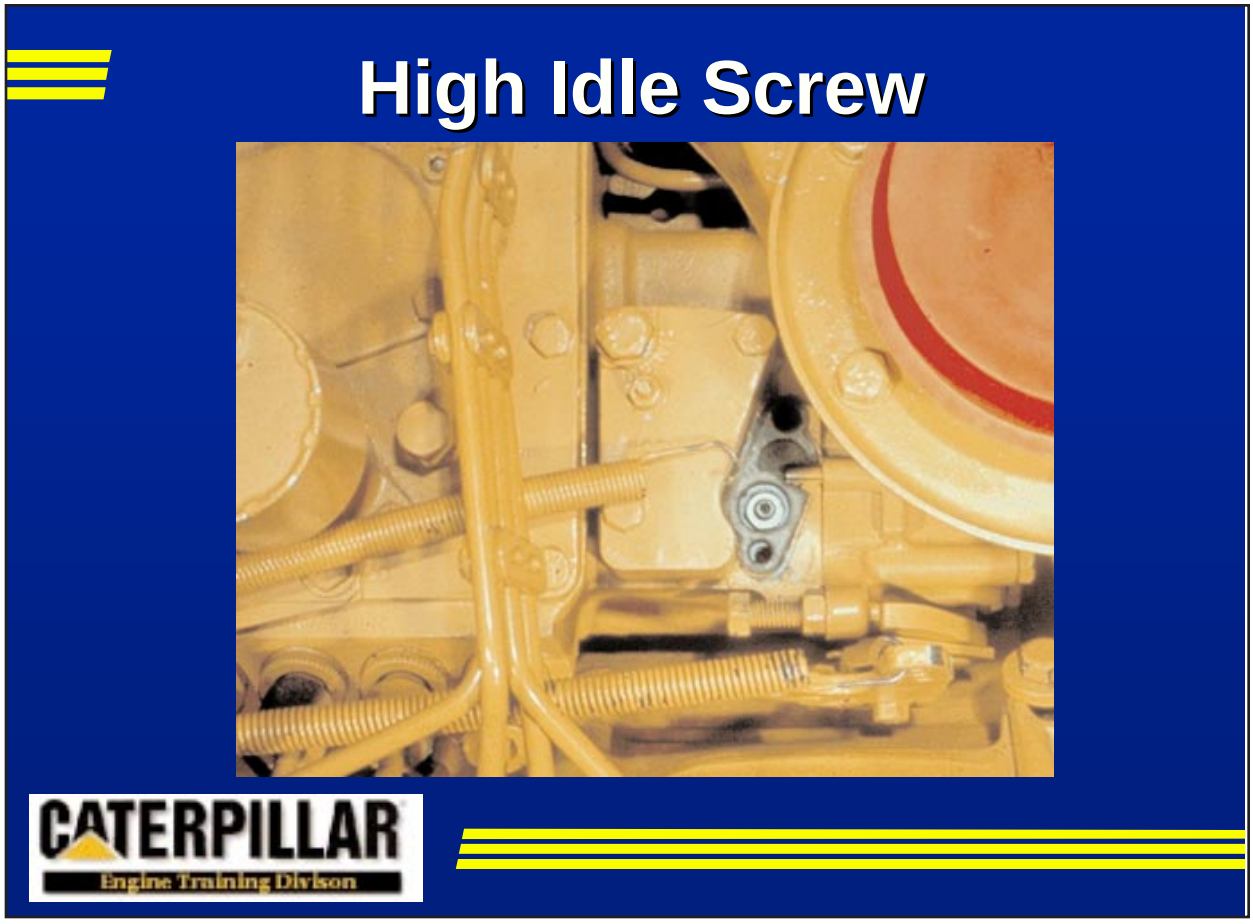
CAUTION: Note that the fuel which escapes from the valve will drain from a hose on the outside of the engine. Care should be taken so this f;uel does not fall to the ground becoming an enviromental hazard.



SLIDE 177

Fuel Priming Pump

The fuel priming pump is located on the fuel filter base. The priming pump can be used to evacuate any air in the system. To do this, open the air bleed valve and pump the handle until fuel without air comes out of the drain hose. After the air is removed from the fuel pump housing, close the bleed valve. If the air is down stream from the pump, the fuel line nuts at the cylinder head may need to be loosed during operation to bleed air within the lines themselves.

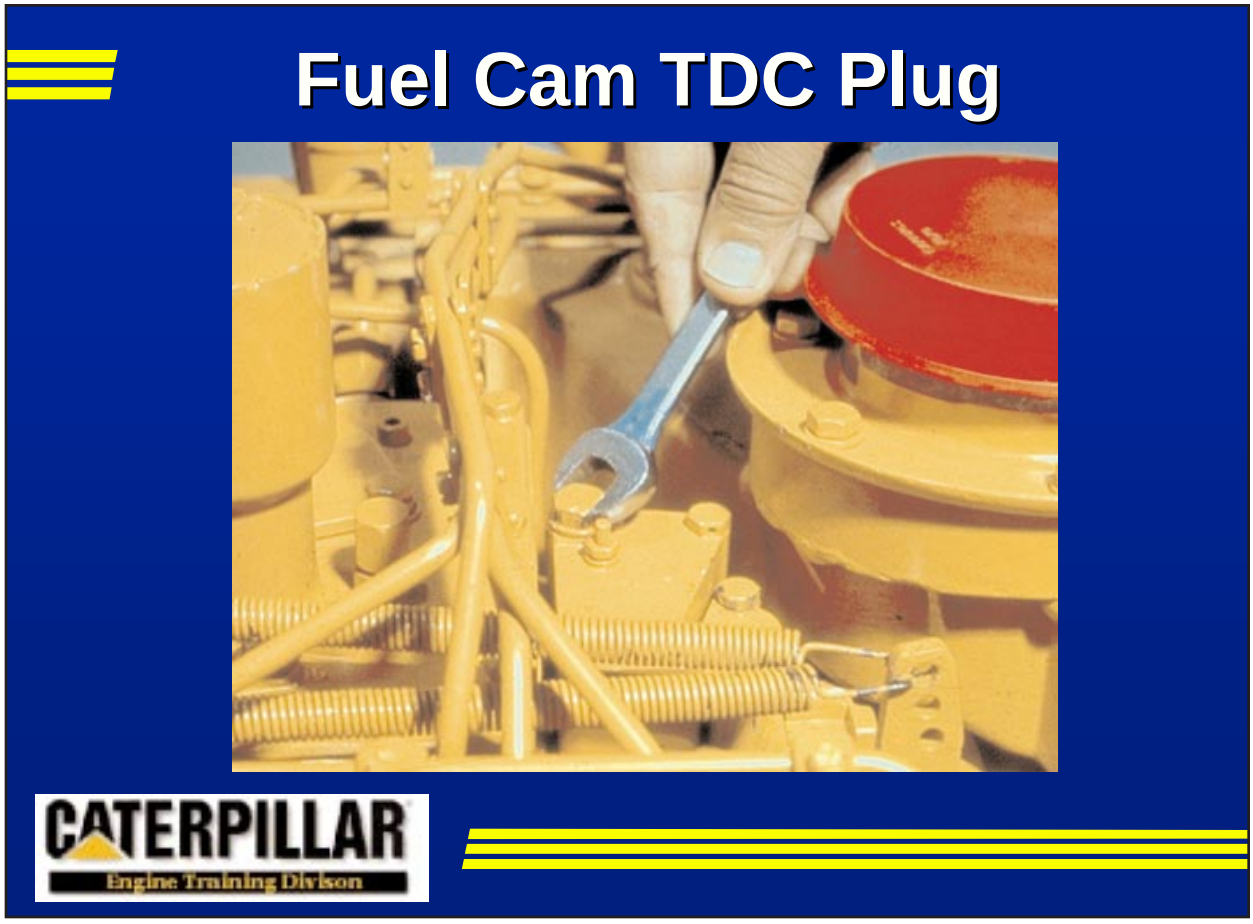


SLIDE 178

Low Idle Adjustment

High Idle Adjustment

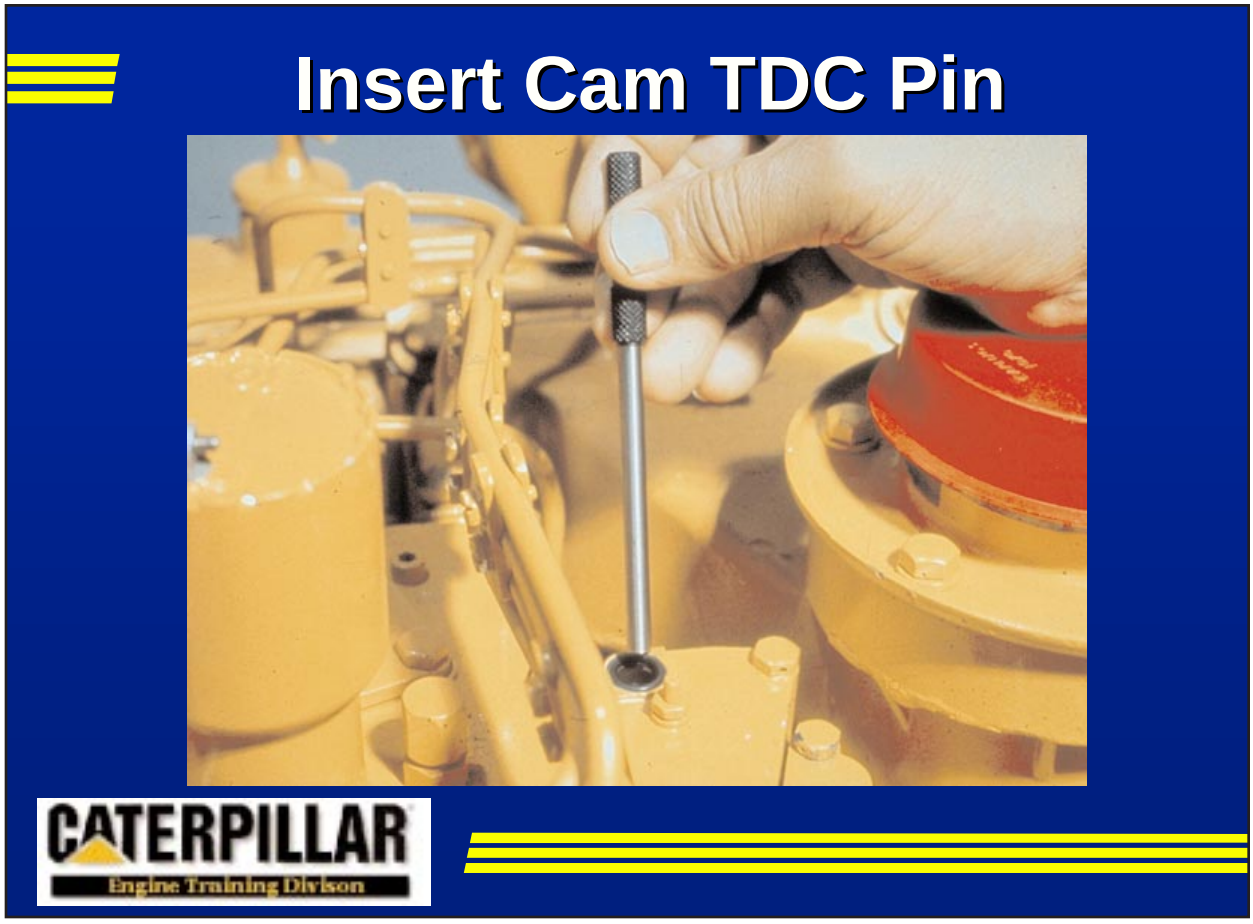
The adjustment screw for low idle is located on the outside left of the governor housing (Just above the lower spring in the picture). The high idle screw is located under a cover on the top of the governor housing (the unpainted screw and locknut).



SLIDE 179

Check Timing

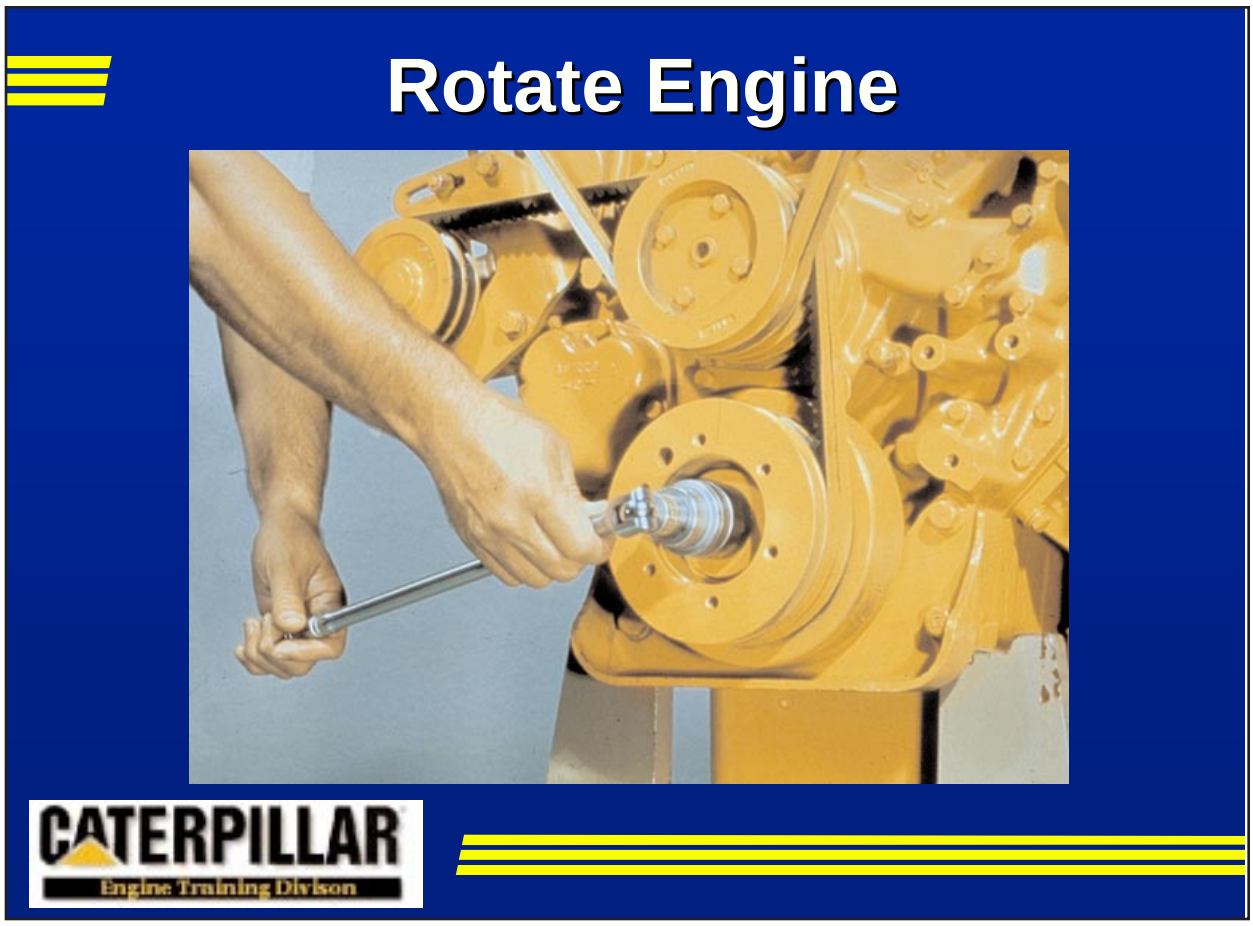
To check the timing of the fuel pump camshaft, remove the bolt shown on the top right side of the governor housing



SLIDE 180

Timing Pin

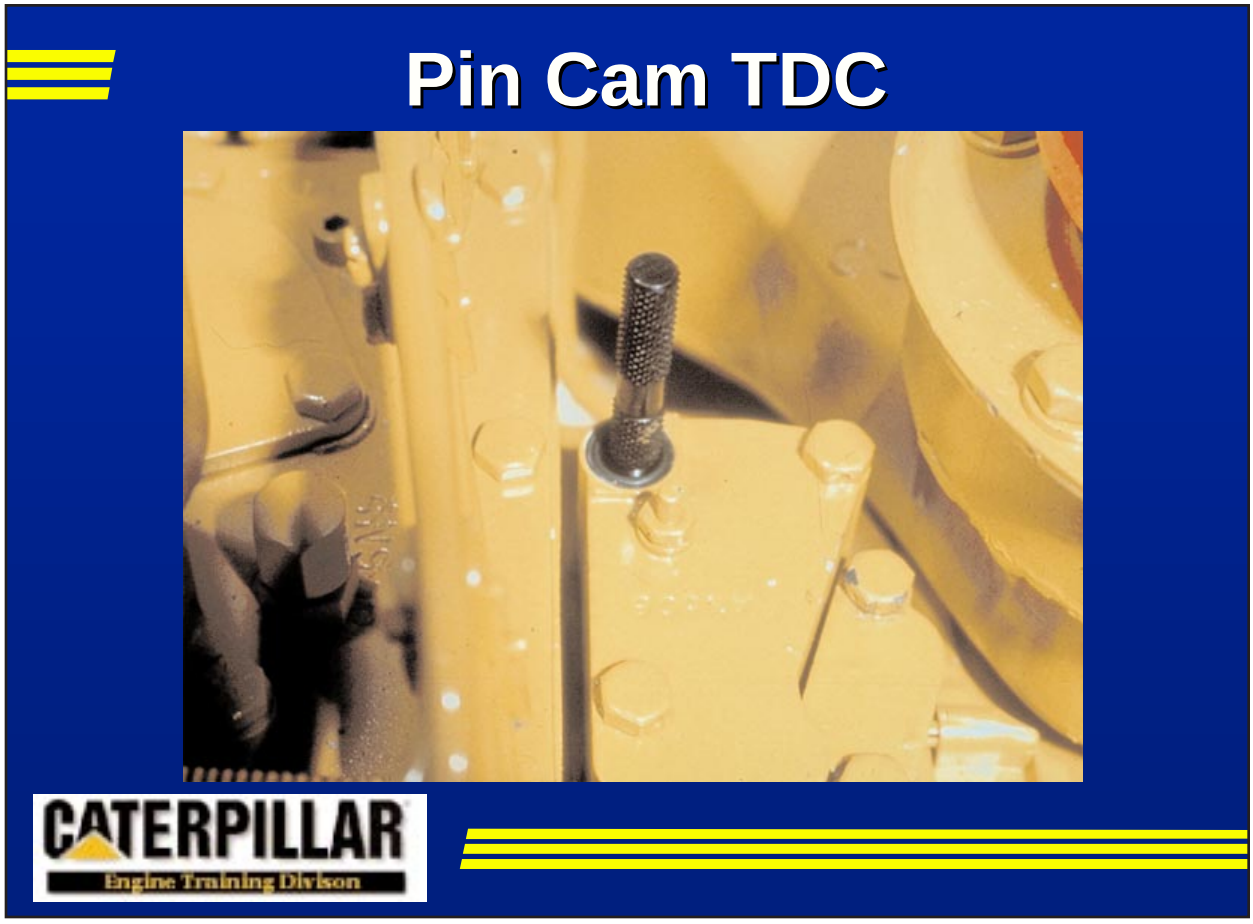
Drop the timing pin into the timing pin hole.



SLIDE 181

Rotate the Engine to TDC

Rotate the engine in the direction of engine rotation until the TDC-1 mark on the damper and the pointer are in alignment.



SLIDE 182

Mark on Damper

Pointer

The timing pin should fall into the slot in the fuel pump camshaft when the mark on the damper and the pointer are in alignment.

SLIDE 183

Remove Plug

Remove the plug from the timing bolt hole. With a 5/16 bolt (the one shown loose at the lower right hand corner) from the front housing, insert it into the hole for the timing bolt (lower right side of pulley out of the picture) and turn it into the threaded hole in the valve camshaft gear. If the timing pin goes into the groove in the slot in the injection pump camshaft and the bolt will turn into the valve camshaft gear, the timing of the engine is correct. If the bolt will not turn freely into the gear, the timing is not correct.

SLIDE 184

Changing Pump Timing

Tachometer drive adapter

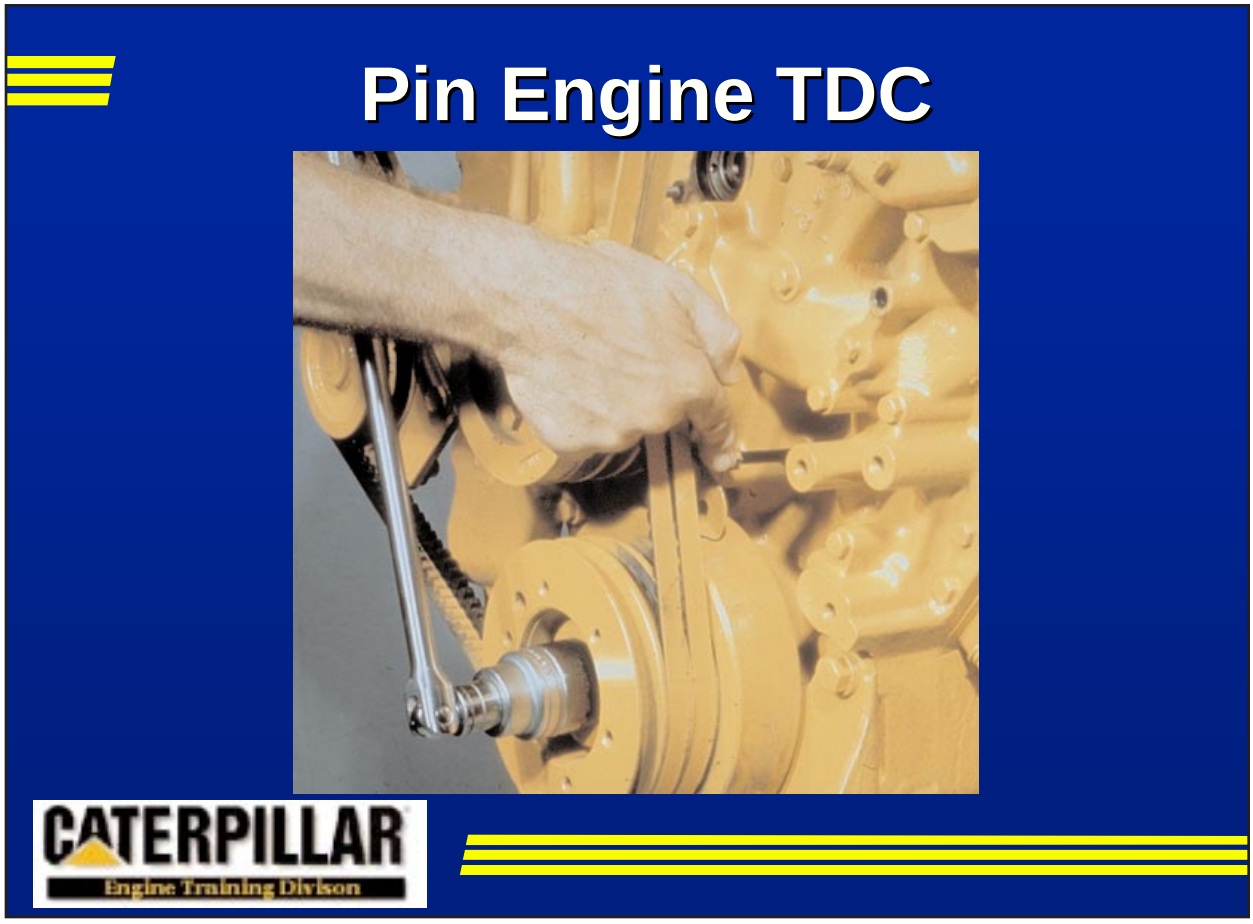
To change the fuel pump timing, first remove the tachometer drive adapter.

This bolt/sleeve is the tachometer drive. It also holds the drive gear of the injection pump camshaft on the tapered drive flange on the end of the camshaft and fastens them together.

SLIDE 185

5P2371 Puller Plate

Remove the bolt using a deep socket wrench. Using the 5P2371 Puller Plate, lossen the drive gear from the tapered drive of the injection pump camshaft. CAUTION: Use this puller to prevent damage to the camshaft of the injection pump and the shield for the flyweights in the governor and the housing. Turn the bolts evenly a little at a time to push the camshaft drive from the drive gear.



SLIDE 186

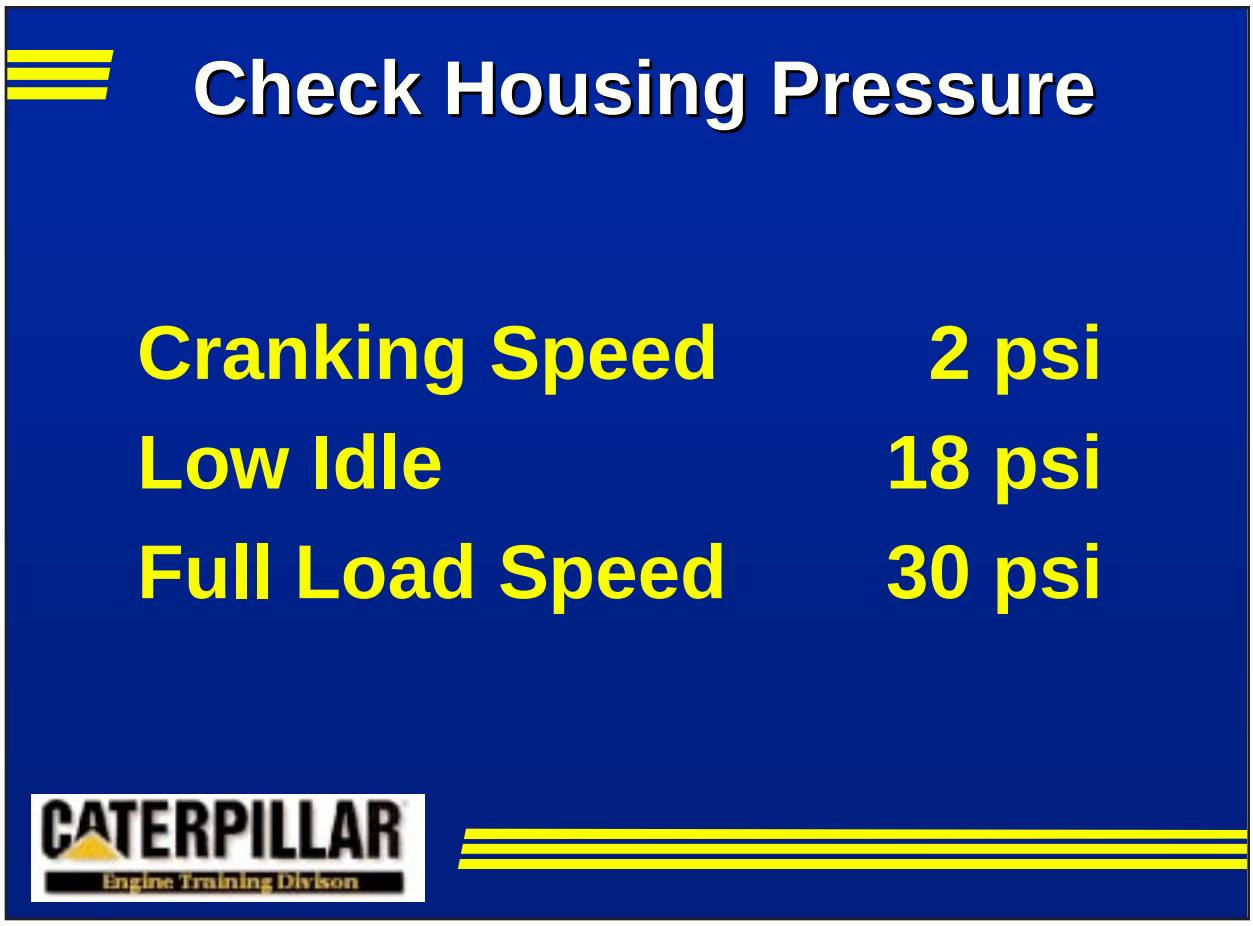
Turn the crankshaft clockwise

Here we see the drive gear loose on the camshaft of the injection pump. The timing pin is in the groove of the camshaft. Now we can adjust the timing of the crankshaft to the fuel injection pump. Turn the crankshaft 90 degrees or more counterclockwise to be sure all clearance is out of the timing gears. Then turn the crankshaft clockwise until the timing bolt goes into the valve camshaft gear. The timing of the fuel injection pump to the engine is now correct.

SLIDE 187

Correct torque

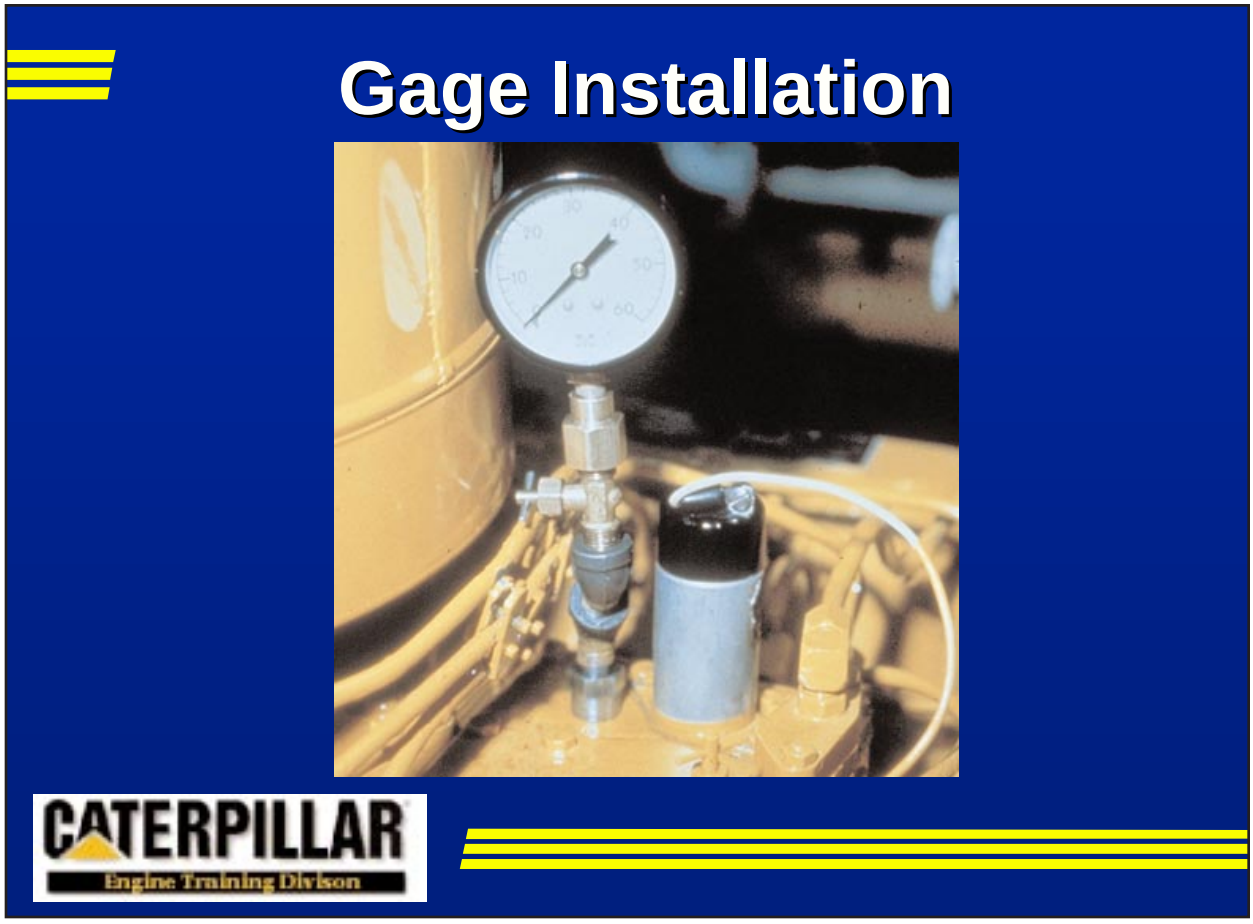
While the timing pin and the timing bolt are installed, turn the tachometer drive bolt with the washer into the end of the camshaft. Tighten the bolt to the correct torque specification. Remove the timing bolt and timing pin. Turn the engine crankshaft two revolutions and check the timing again. This makes sure that the timing is correct.



SLIDE 188

Fuel housing pressure

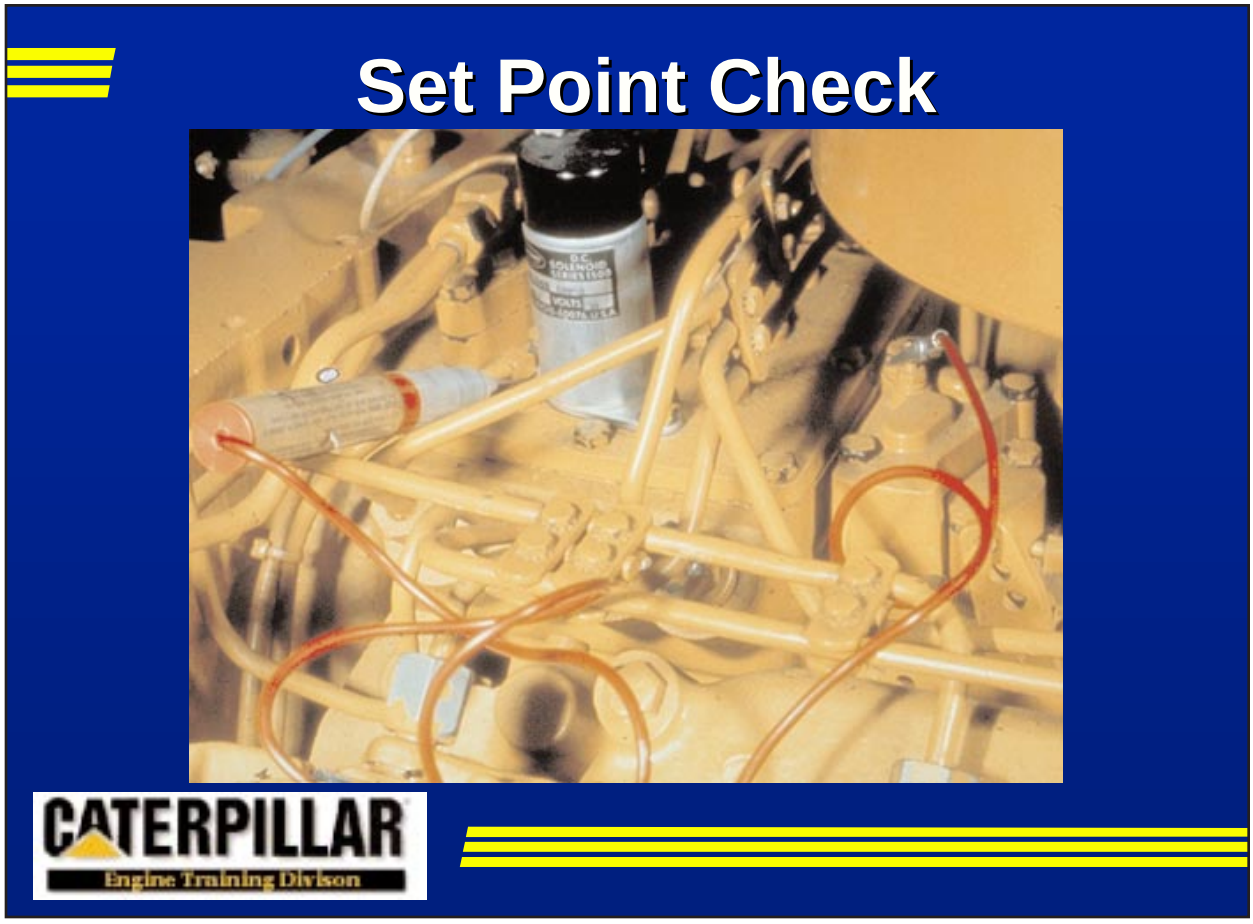
One of the fuel system checks is the housing fuel pressure. This is normally done in-chassis at rated speed. If the housing is checked on the fuel injection test bench, checks should be made at three different speeds, cranking, low idle and rated speeds, to be sure that the engine is operating properly.



SLIDE 189

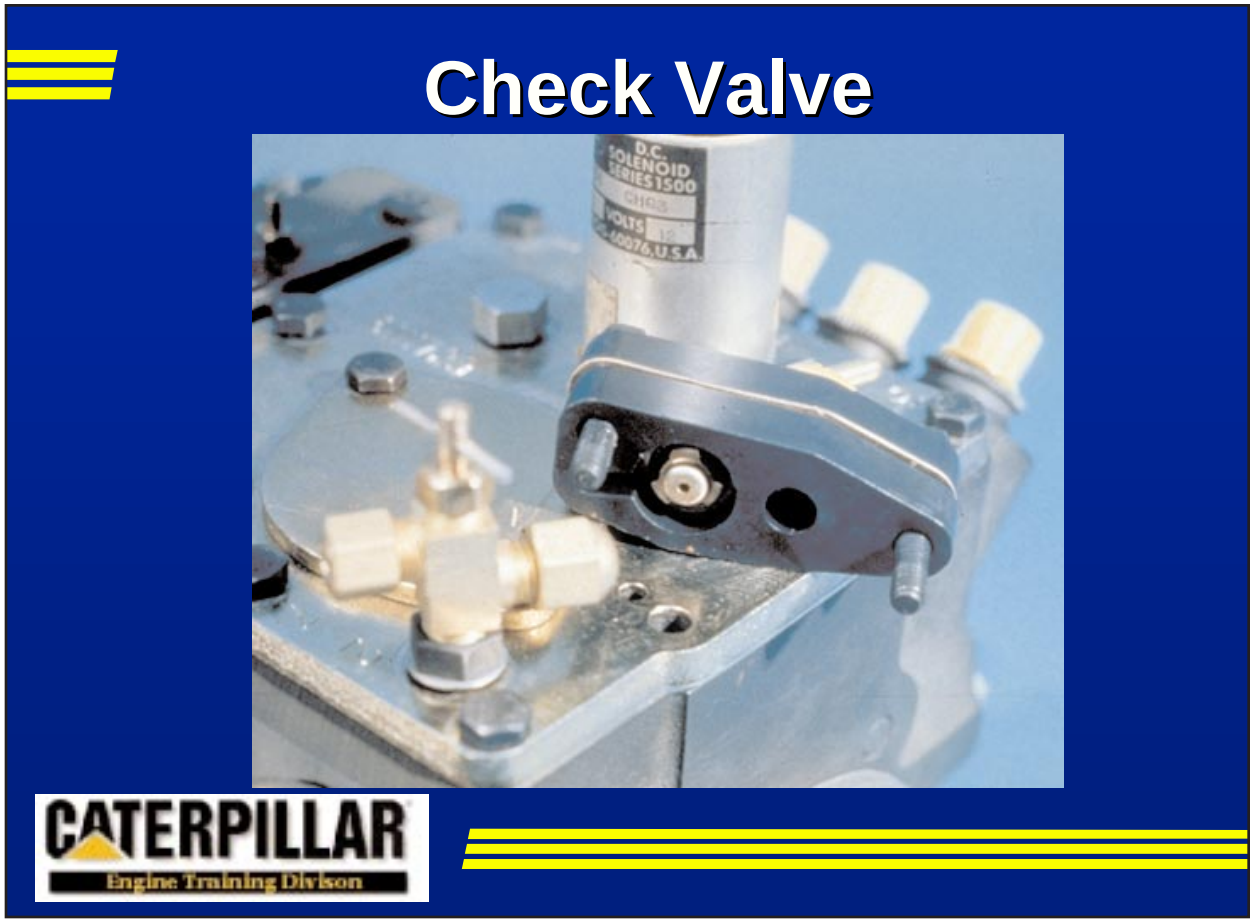
0-60 psi pressure gauge

Remove the plug on the top of the housing. Install a fitting and a 0-60 psi pressure gauge. Start the engine and bring it to normal operating temperature. Record the pressure reading at rated speed. Compare this number to the specification in the service manual.



SLIDE 190

To check set point of the engine, attach a multitach/set point indicator to the engine. The continuity screw is shown here with an indicator light attached to it instead. Make sure that any paint is removed from the brass terminal prior to running the test. With the tool in place, run the engine until it is at operating temperature. Bring the engine to high idle and load it until set point rpm is displayed.. Repeat the test 5 times and average the results to obtain a proper set point rpm. Compare this rpm to the specification found on the engine data plate. If the plate is missing, consult SIS, SIS Web or AIMS.



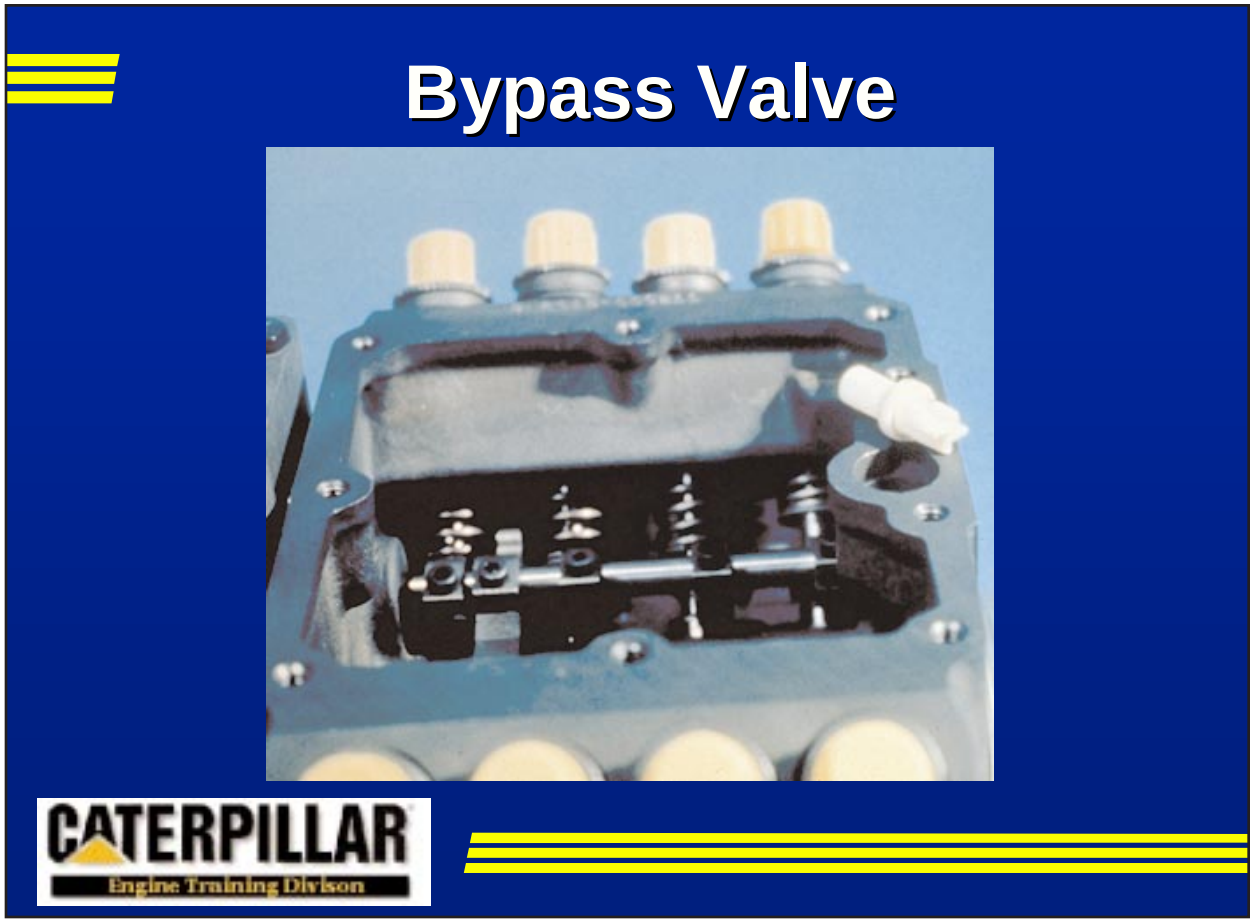
SLIDE 191

Removal of fuel injection pumps

To remove the fuel injection pumps, first disconnect the fuel supply and bypass lines from the fuel injection housing. Drain the fuel from the housing and plug all openings. Some of the earlier housings require the fuel to be pumped or siphoned out. Remove the check valve flange bolts and check valve flanges.

The check valve maintains system pressure to a maximum of 30 psi at full load. It is a constant metering valve that sends about 9 gallons per hour back to tank. No return flow exists until 8 +/- 3 psi has been obtained in the housing.

The return allows removal of entrained air and fuel cooling.

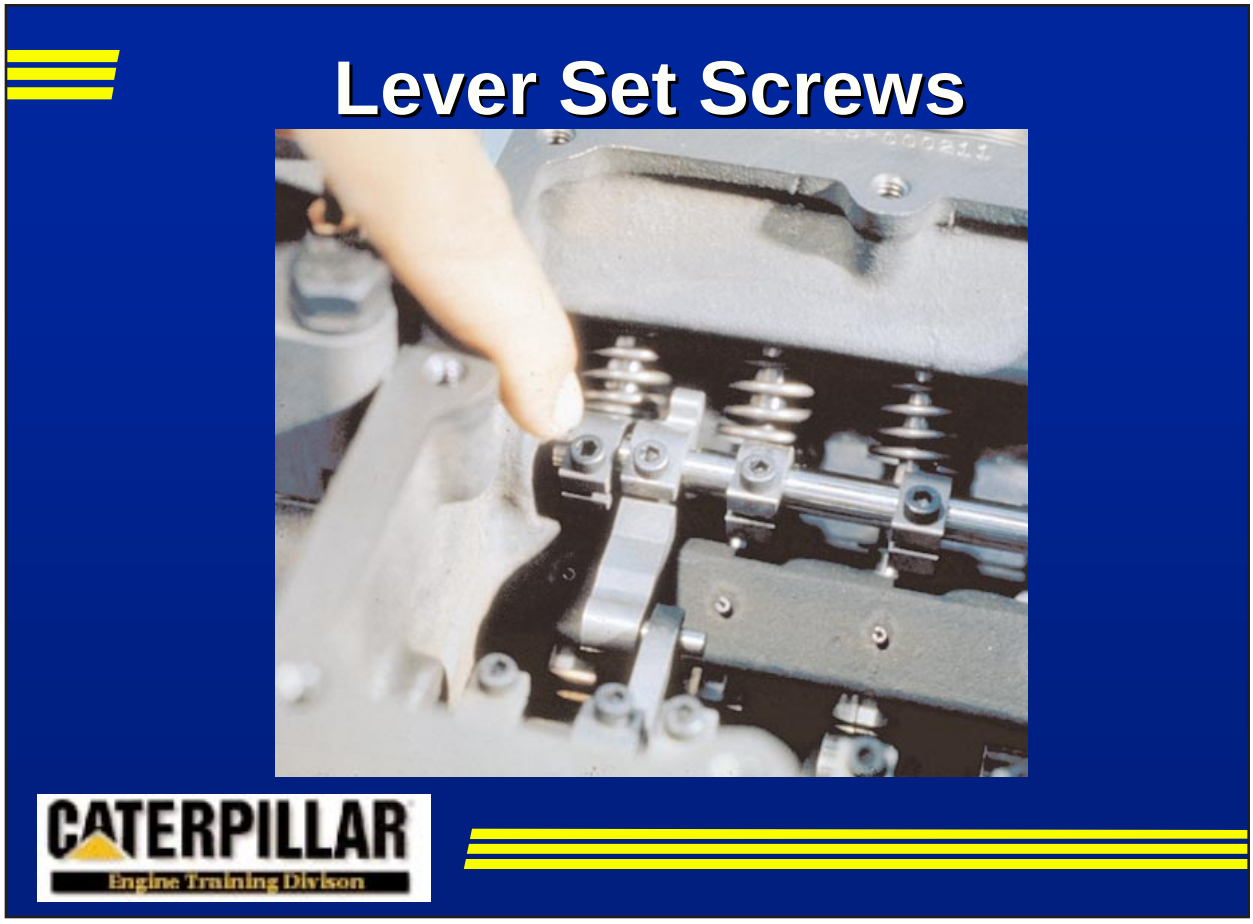


SLIDE 192

Remove cover

Remove valve and spring

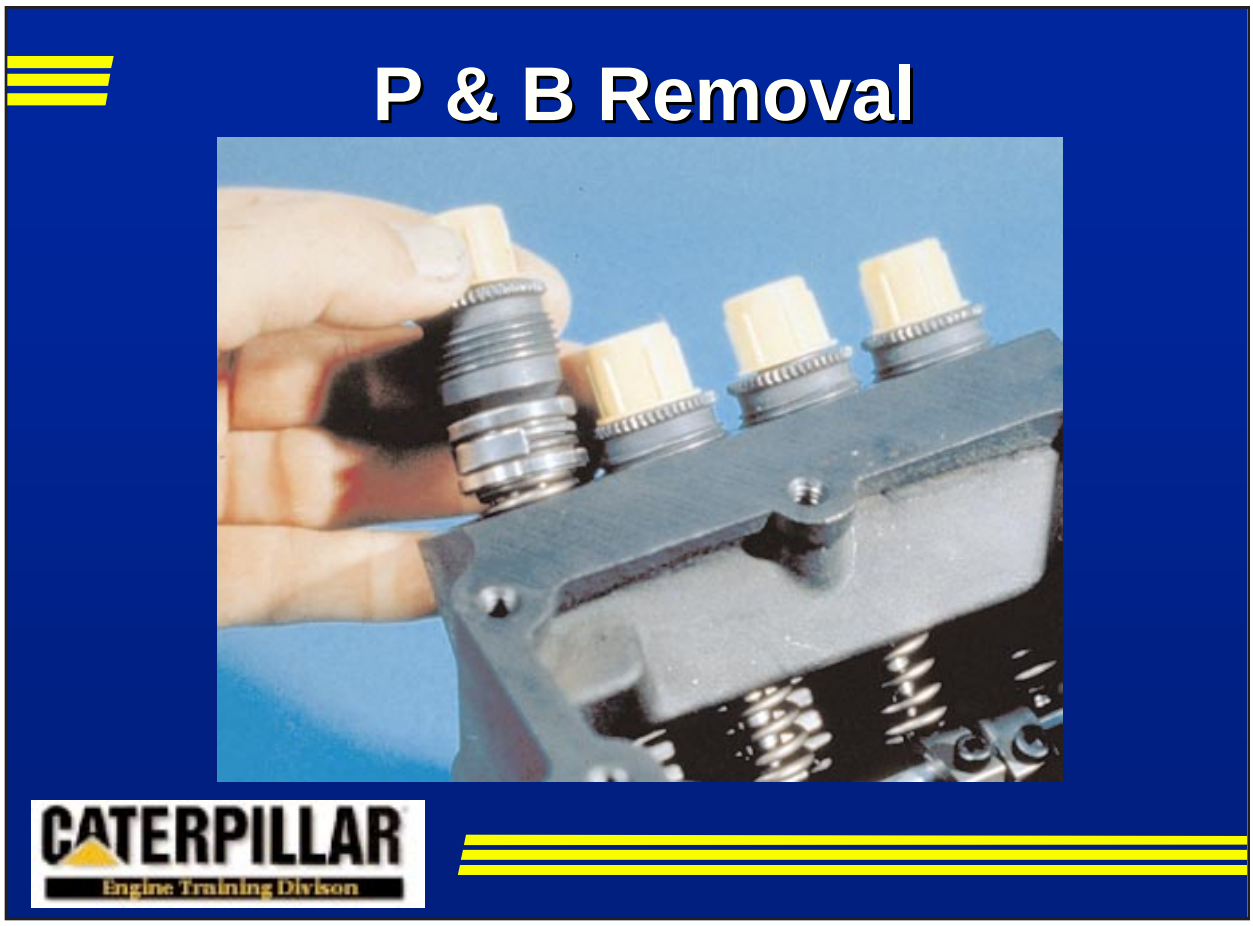
Remove the bolts that hold the cover to the pump housing and lift off the cover. Remove the bypass valve and spring.



SLIDE 193

Moving the levers changes calibration

Do not loosen the screws that hold the levers to the fuel control shaft when removing or installing the pump assemblies. If the levers are moved, the fuel pump calibration will be changed.



SLIDE 194

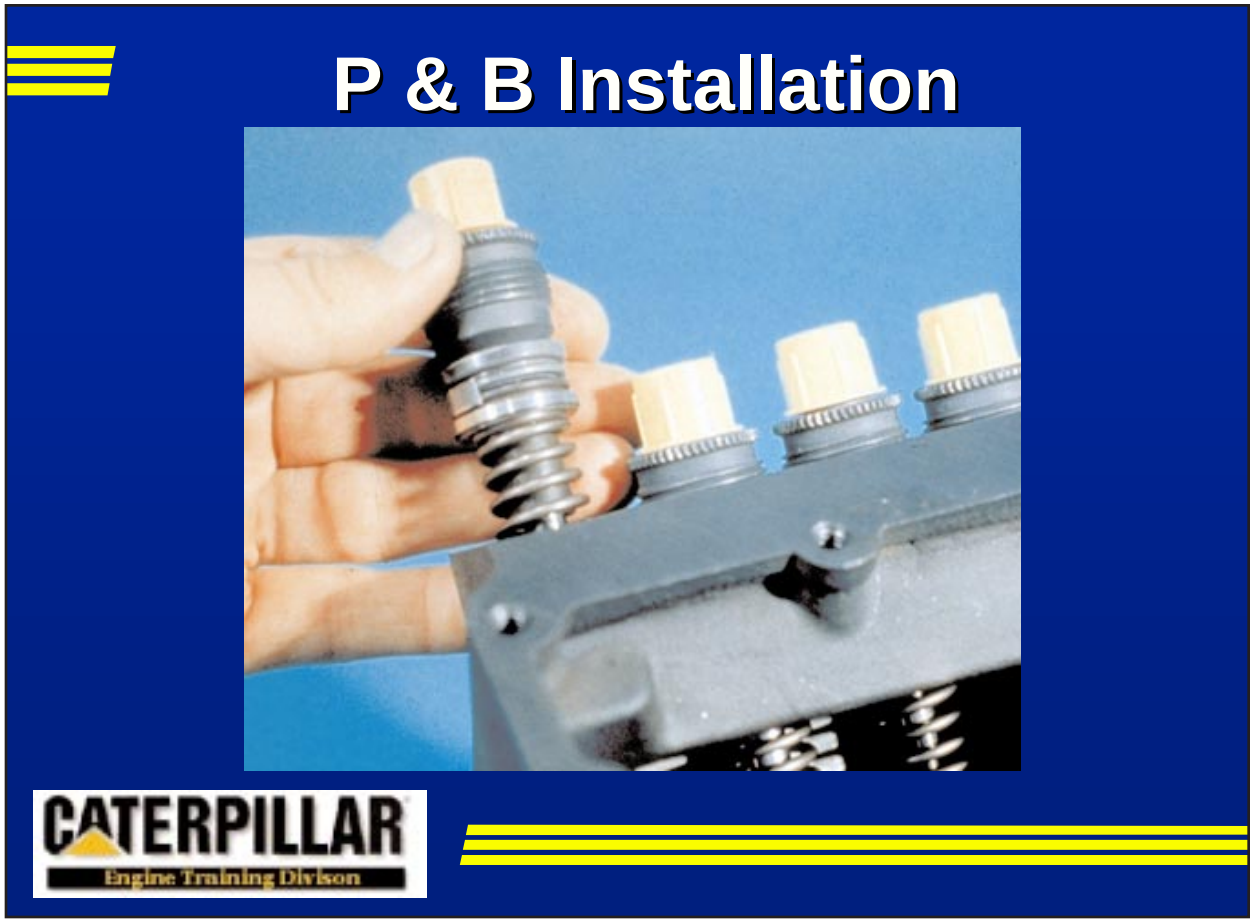
Remove P & B assemblies

To remove the fuel injection pumps, install the 8S2243 wrench. Turn the wrench and lossen the bushing of the injection pump. Remove the pump and mark its location. The sleeve may drop off the plunger when the pump assembly is removed. It can be removed from the pump housing with a magnet.

SLIDE 195

Install P & B assembly

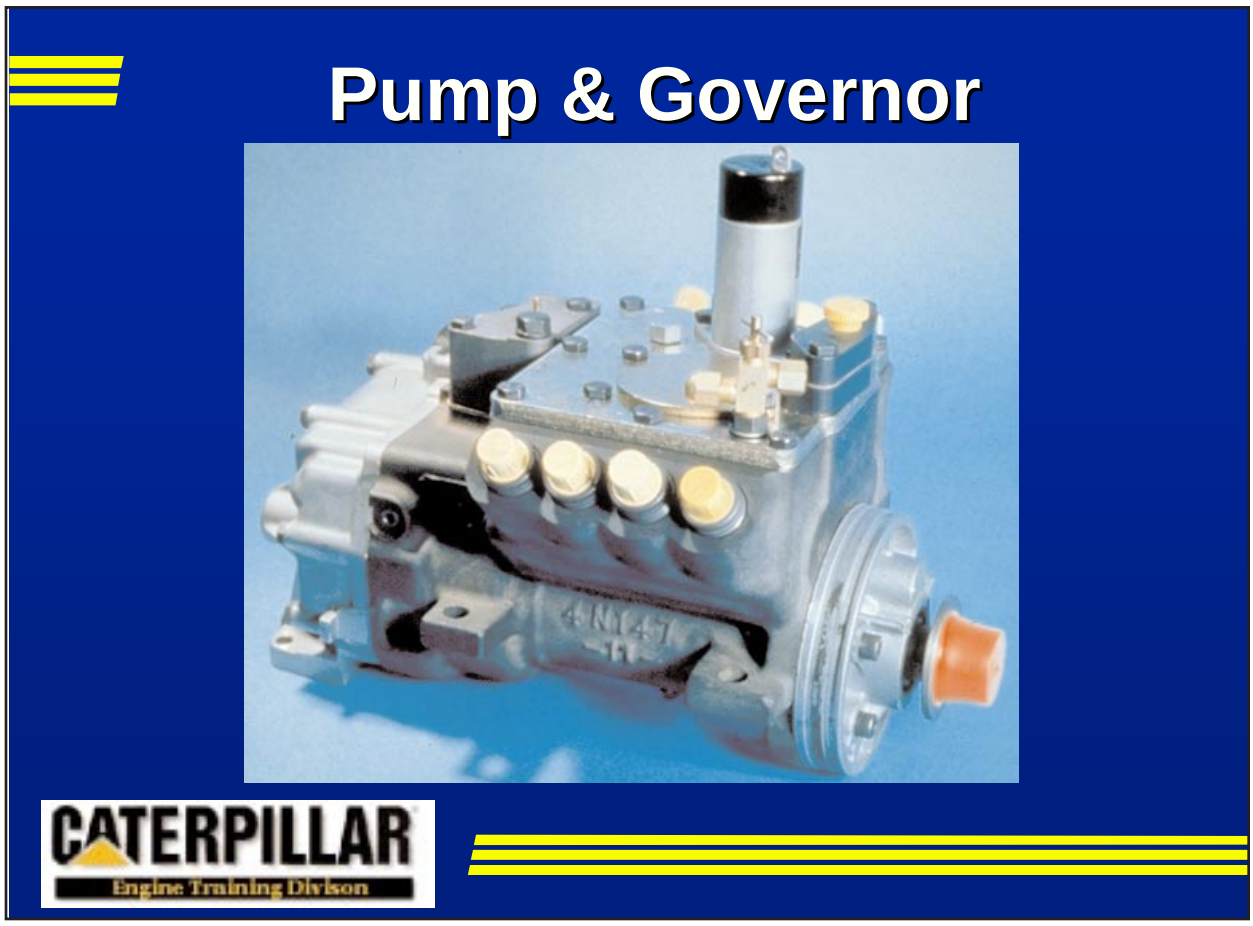
To install the injection pump, put the sleeve on the plunger with the thin flange of the sleeve toward the barrel as shown. Turn the camshaft of the injection pump so that the lifter is on the lowest place on the cam. Move the governor control to the high idle position. These actions will make installation of the pump easier.



SLIDE 196

P & B assembly straight into bore

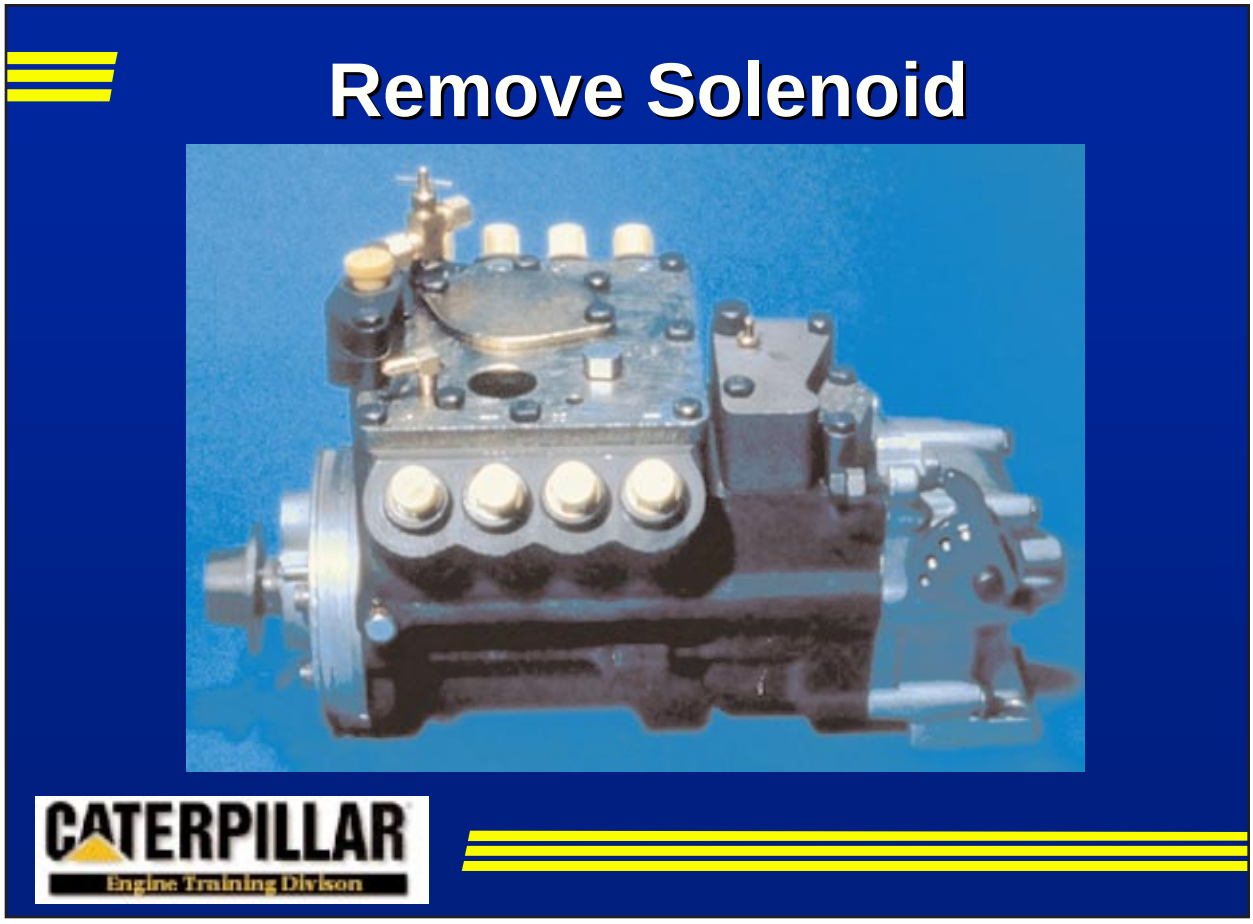
Put the injection pump straight down into the bore. If necessary, use a finger to guide and hold the sleeve as you fit the lever into the groove of the sleeve. Tighten the bushing to specifications as listed in the Service Manual.



SLIDE 197

Fuel settings

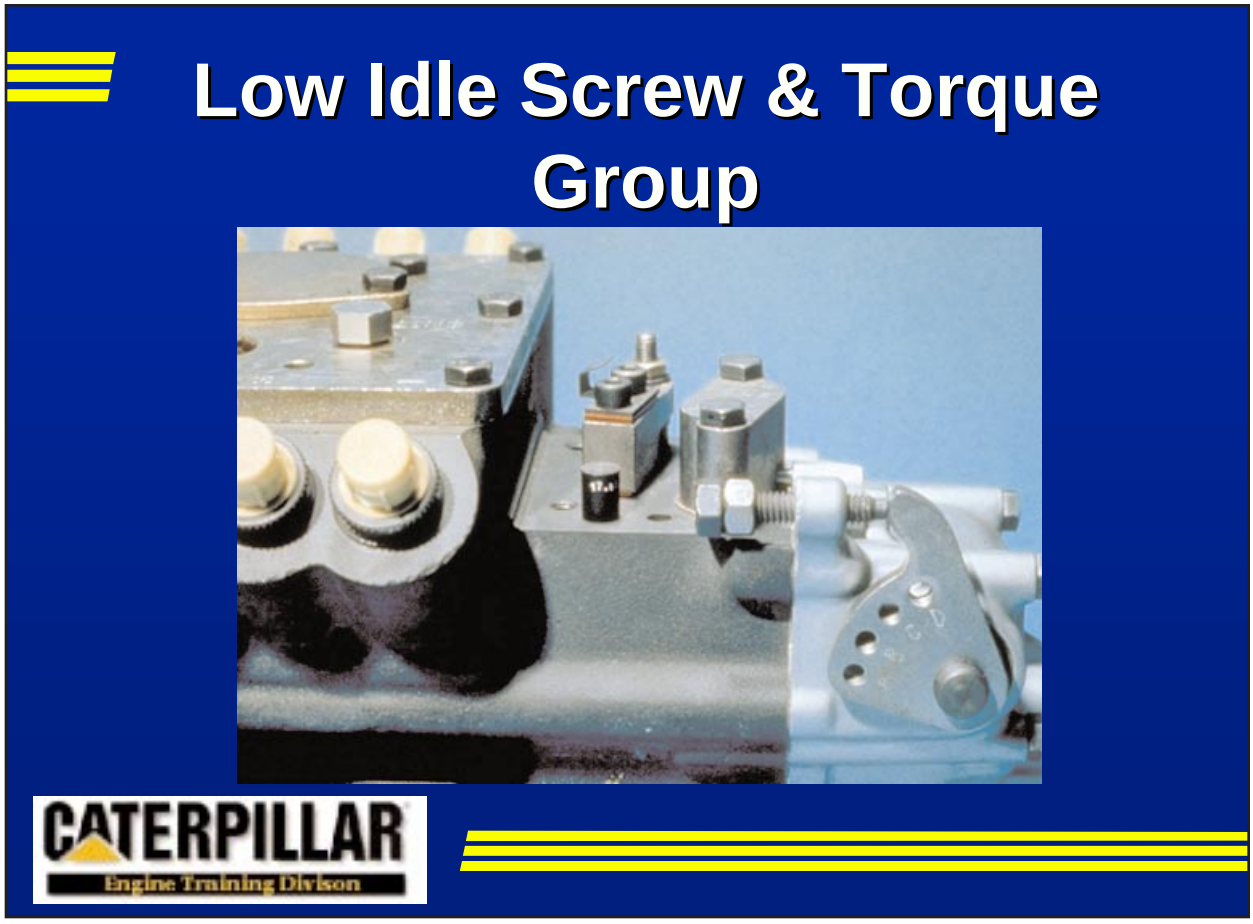
The adjustment of the fuel settings can be done with the housing for the fuel injection pumps either on or off the engine. We show the procedures with the housing off the engine.



SLIDE 198

Remove shutoff solenoid

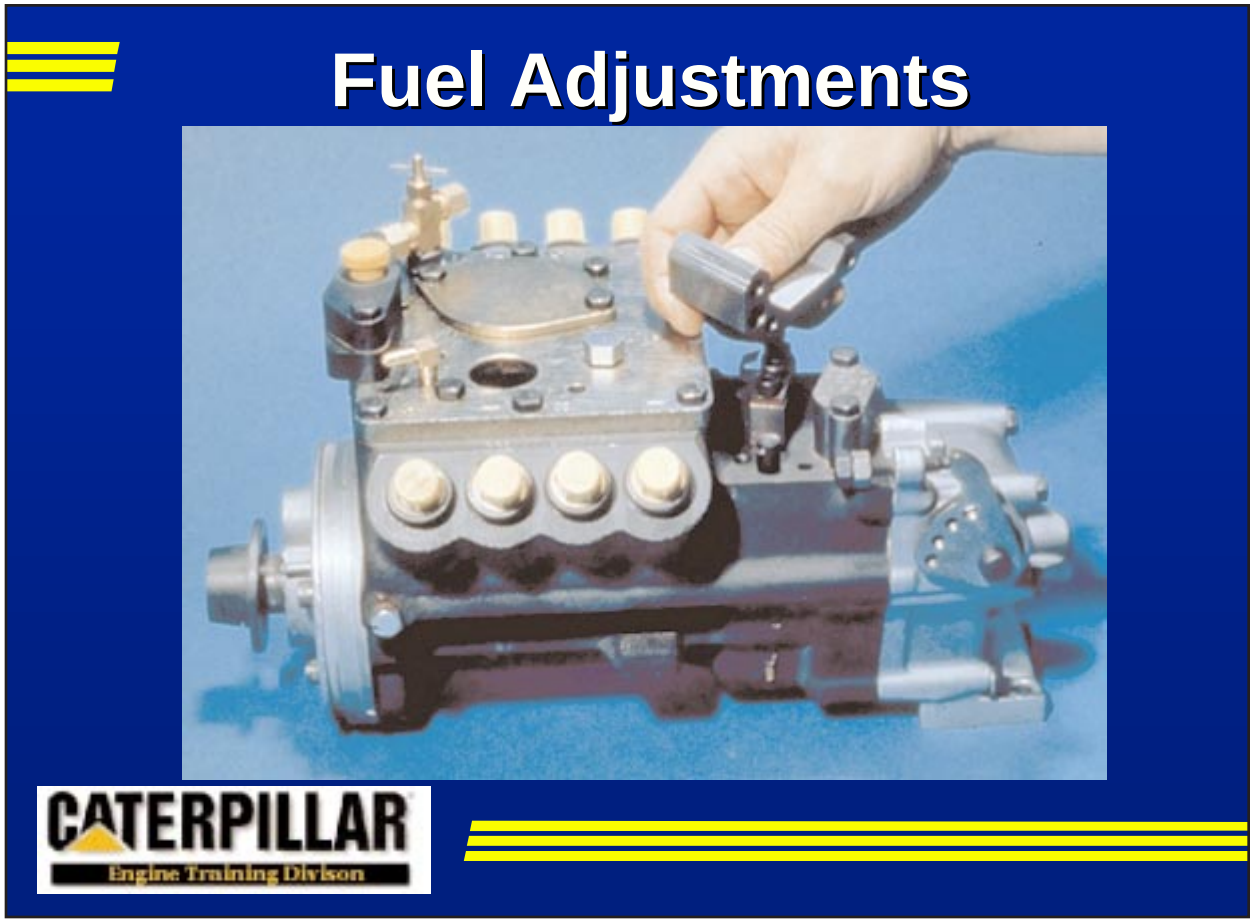
Remove the fuel sutoff solenoid. This step is necessary to permit full movement of the fuel control linkage in the governor while making the fuel setting adjustments.



SLIDE 199

Install pin

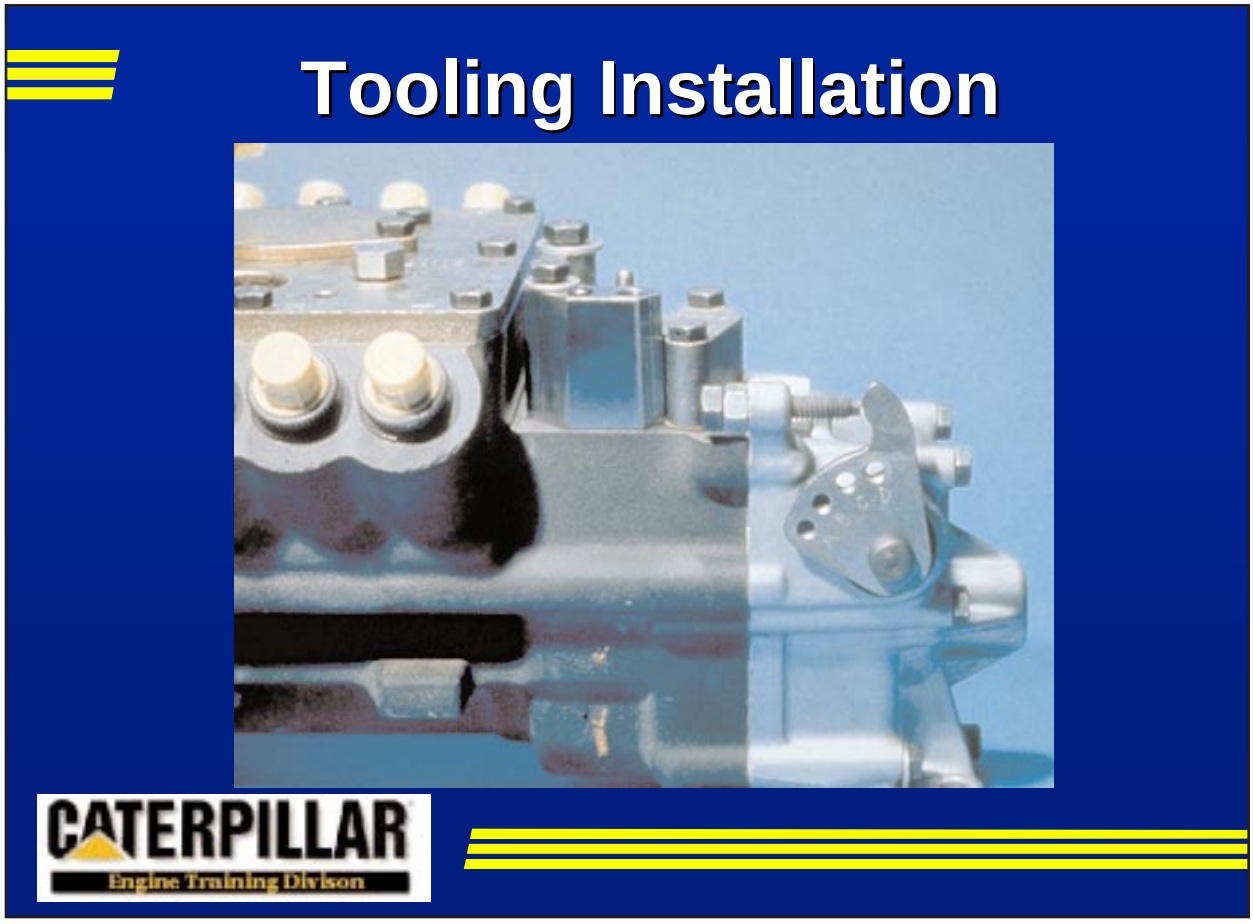
Select the correct zero set pin. The 5P0298 pin with 17.8507 stamped on the large diameter is the correct one for the fuel setting on vee-type pumps. Put the pin into the hole in the housing.



SLIDE 200

5P4226 Adapter pin

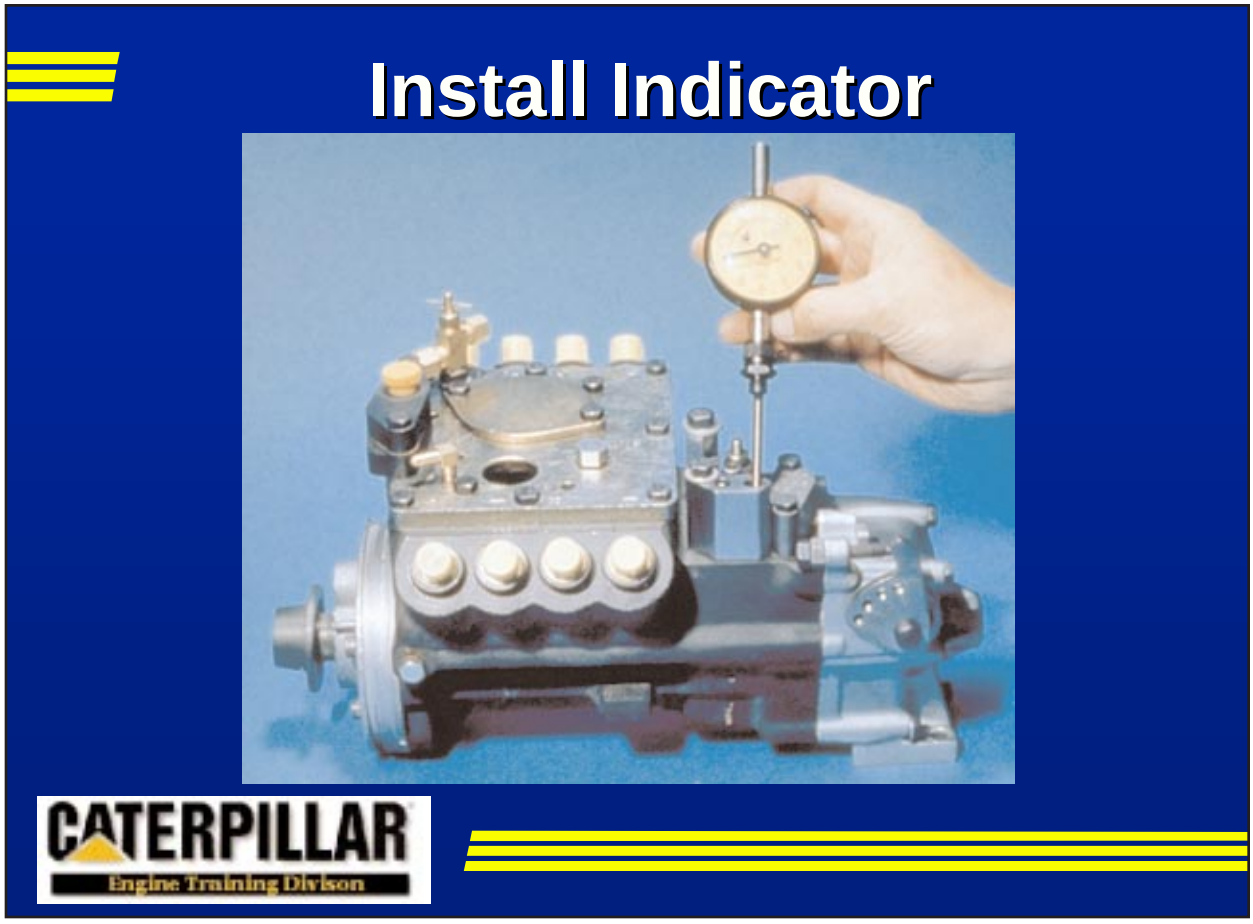
Place the 5P4226 adapter over the zero set pin. Do not use a gasket under the adapter or cover. Install the bolts and fasten the adapter to the housing. Install the 8S7271 set screw in the adapter. Tighten the set screw until the pin is held against the injection pump housing.



SLIDE 201

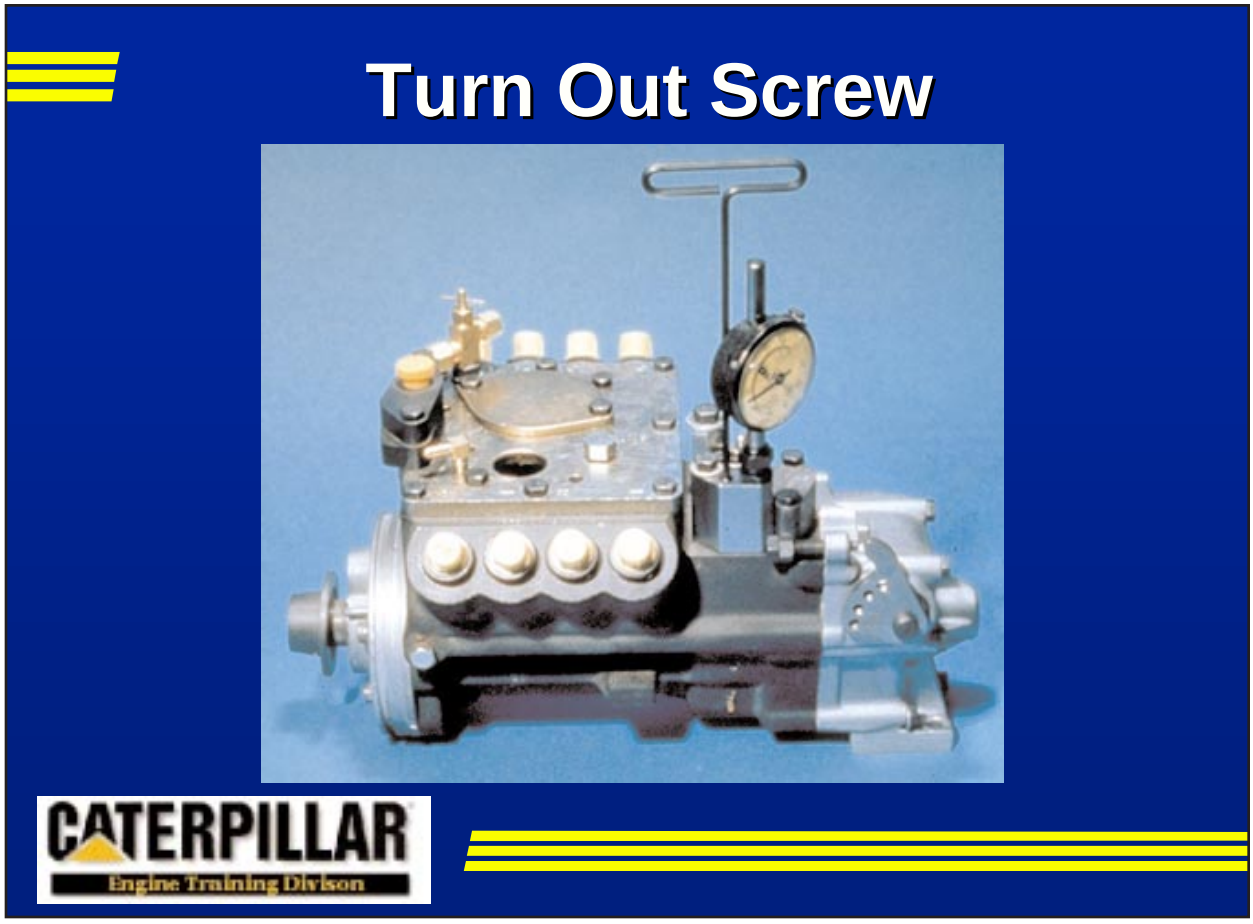
High idle position

Move the governor control to the high idle position and lock it. Here the governor control is held in the high idle position by using the low idle screw.



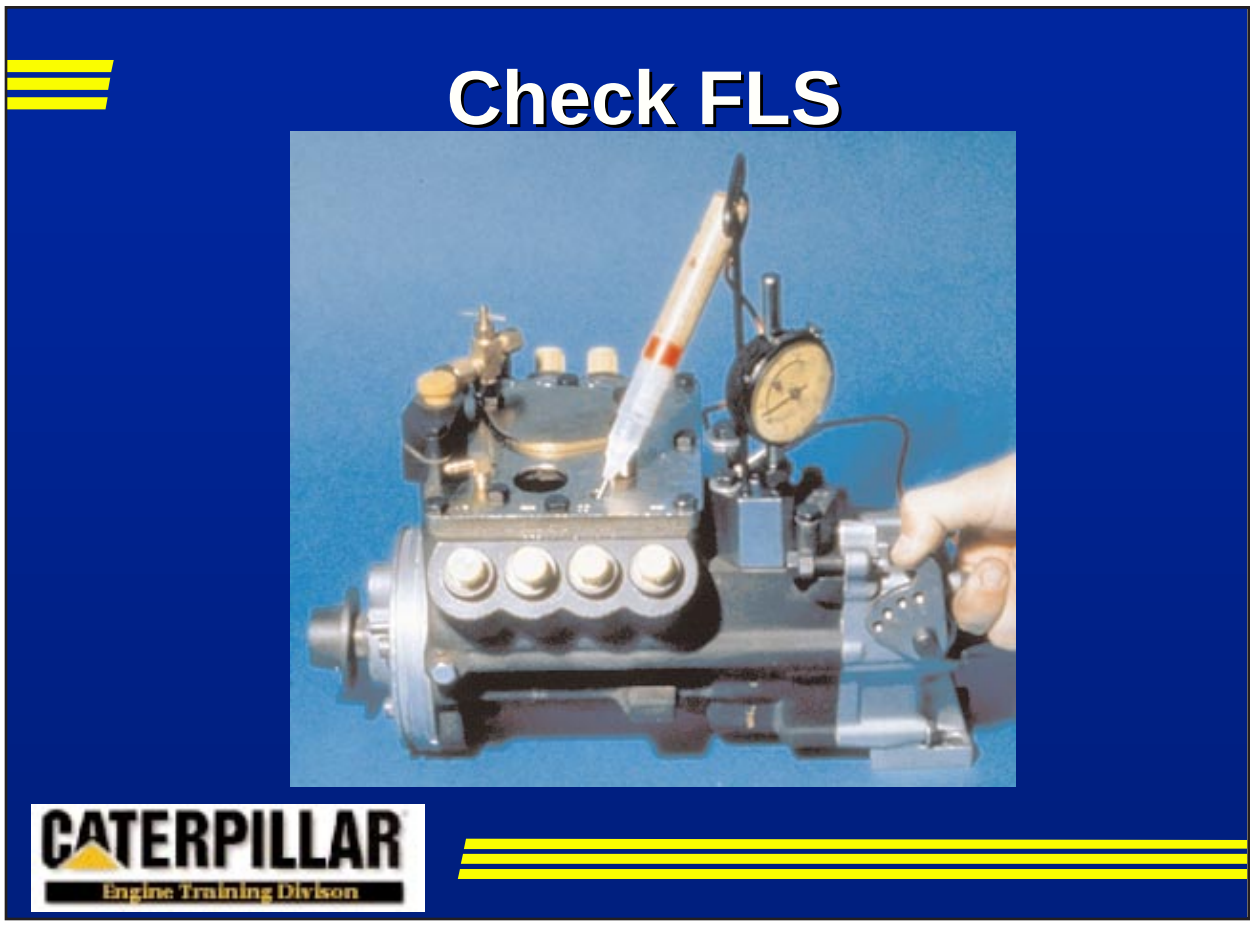
SLIDE 202

Assemble the 3P1567 dial indicator by installing a 57.15 mm (2.25 inch) 5P6531 contact point onto the dial indicator and put it into the 3P1565 collet clamp. Install the collet clamp, tighten and zero the indicator.



SLIDE 203

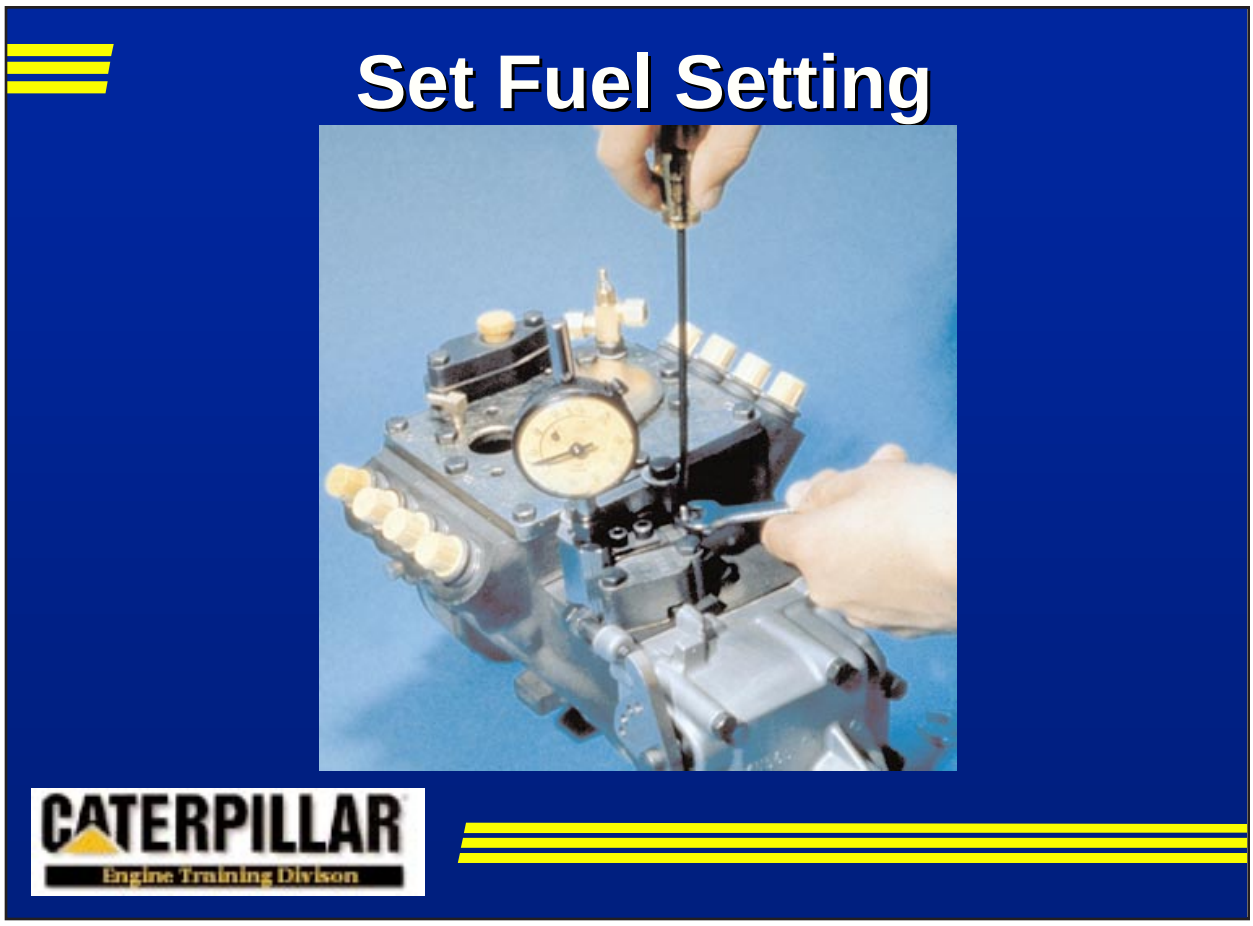
Use the T-handle 5P4205 wrench and turn the zero screw out counterclockwise six or more complete turns. Make sure the dial indicator moves freely as the set screw is turned. Then move the governor control lever to the low idle position. It may be necessary in some intances to adjust the low idle screw for freedom of indicator travel.



SLIDE 204

FLS check

Connect the clip of the 8S4627 circuit tester to the contact spring of the torque spring. Fasten the point of the circuit tester to a good ground on the housing and slowly move the governor control lever toward the high idle position until the circuit tester just comes on. At the exact time the tester comes on, take the reading on the dial indicator. Repeat this procedure several times to make sure the reading is correct. The indicator reading at this point, minus the recorded zero reading, is the fuel setting. If the setting is not correct, an adjustment must be made.

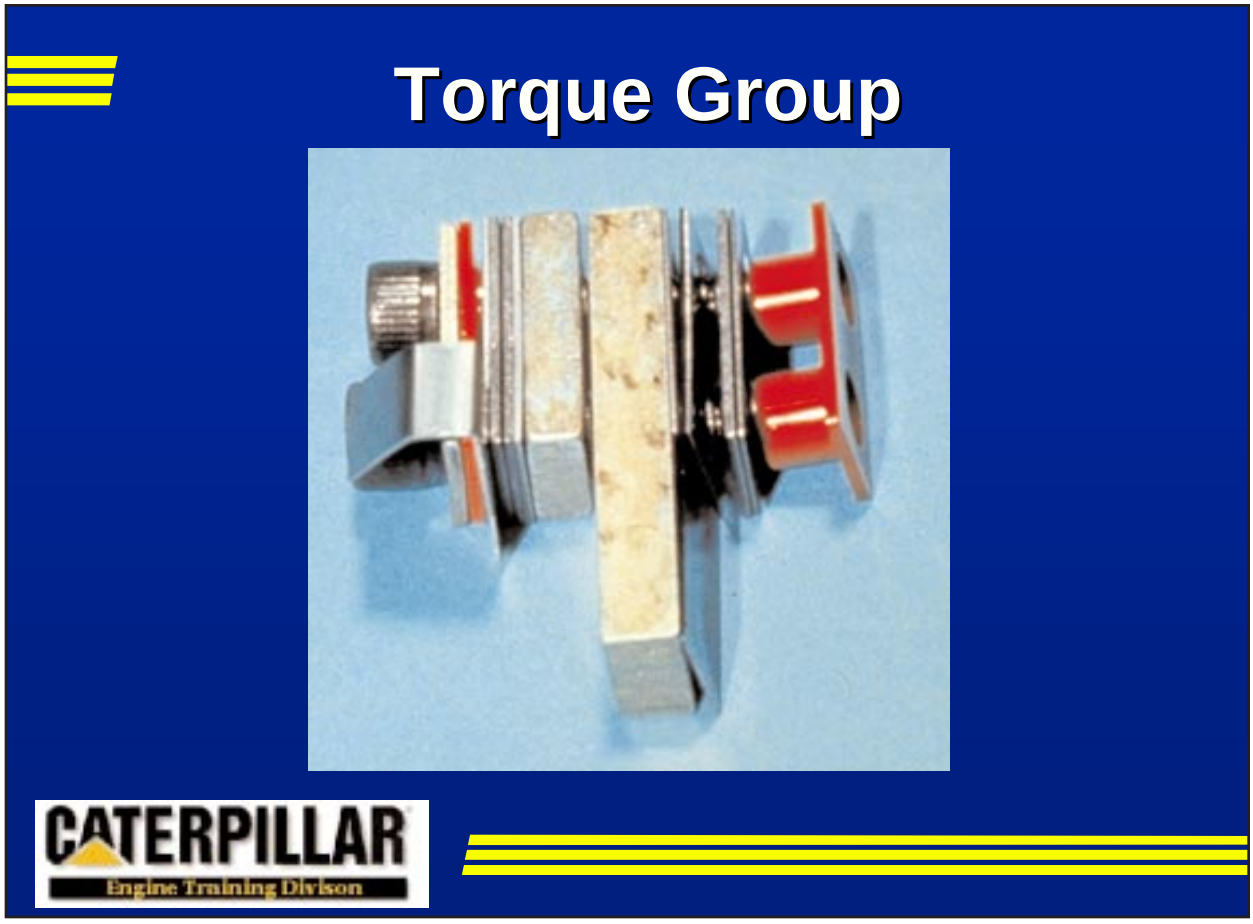


SLIDE 205

Adjust FLS

Recheck

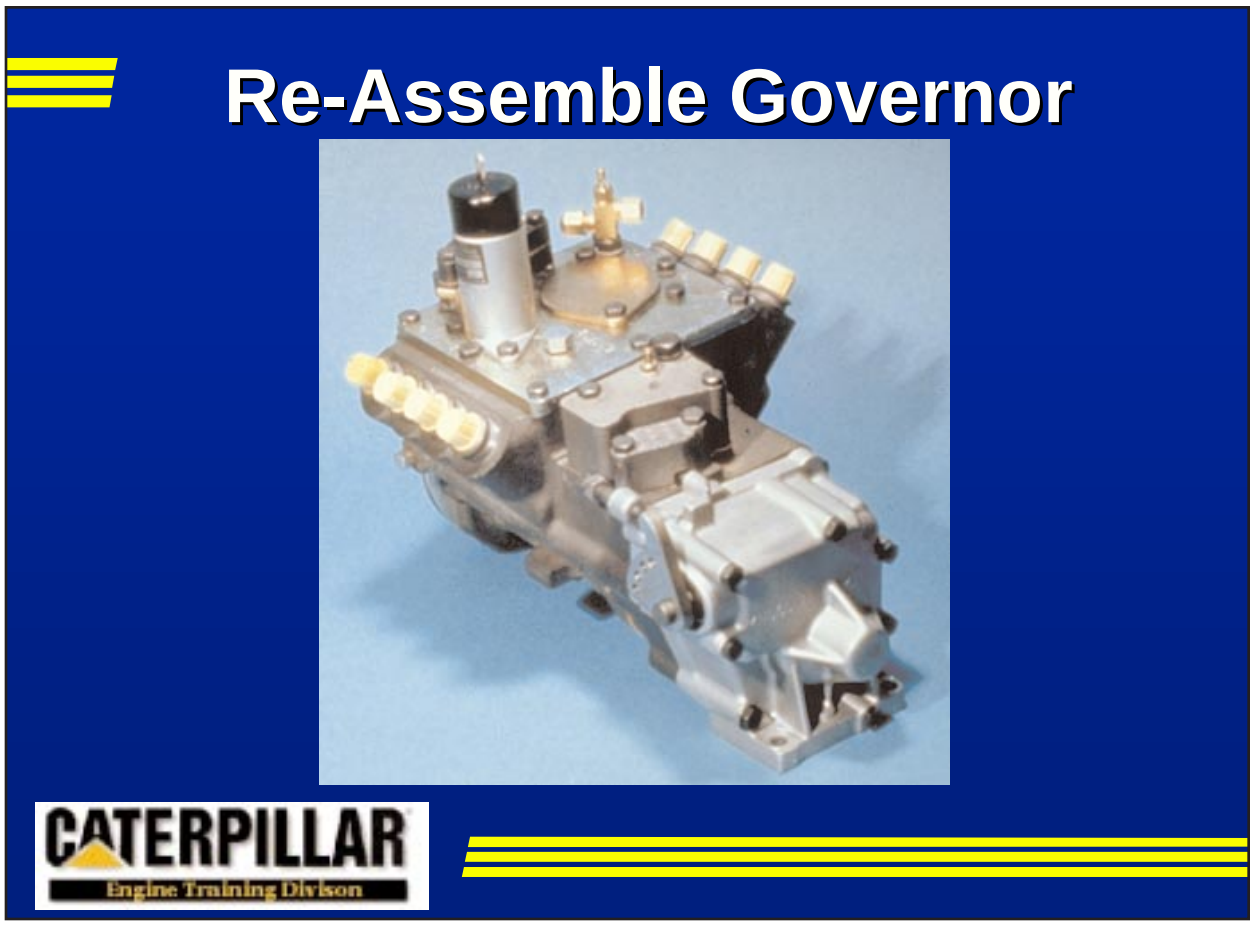
To make an adjustment to the FLS screw, put a wrench on the locknut and loosen it, while holding the adjustment screw with a screwdriver. Turn the adjustment screw until the desired fuel setting is achieved. Hold the adjustment screw with the screwdriver and tighten the locknut. Recheck the fuel setting by repeating the procedure.



SLIDE 206

FTS

After the FLS has been measured and or set, write down the dimension that is on the dial indicator. Then write down the dimension for your engine. Find the difference to determine th number of shims to be removed or installed to bring the FTS (Full Torque Setting) within specifications. Lossen the two bolts holding the shim pack and carefully lift the group out, including the insulator block. Add or remove shims as required to meet specifications. Install the group back on the housing and install the bolts. Do no over torque as this could break the insulator block. Be sure to assemble the torque spring assembly parts correctly in the same sequence as it was disassembled.



SLIDE 207

Recheck settings

Repeat the test procedure to make sure the FLS/FTS are correct and the dial indicator reading is the same as the dimension given for your engine arrangement. Install a new gasket and the torque control group cover. Then install the shutoff solenoid and connect the governor control linkage. Reset low idle adjustment.

SLIDE 208

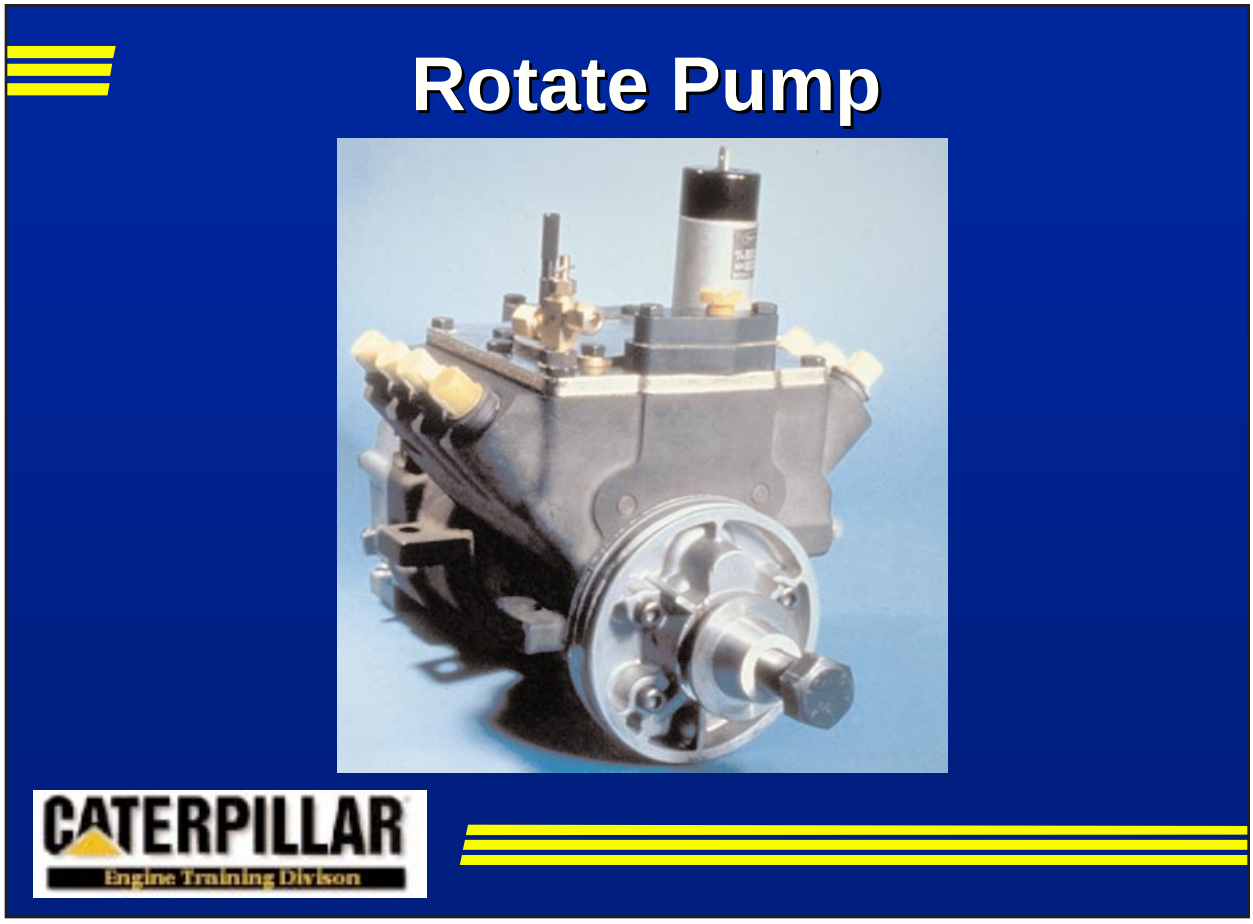
Remove transfer pump

To remove the fuel transfer pump, the fuel pump must be taken off the engine. Remove the large bolt from the torque cover group.

SLIDE 209

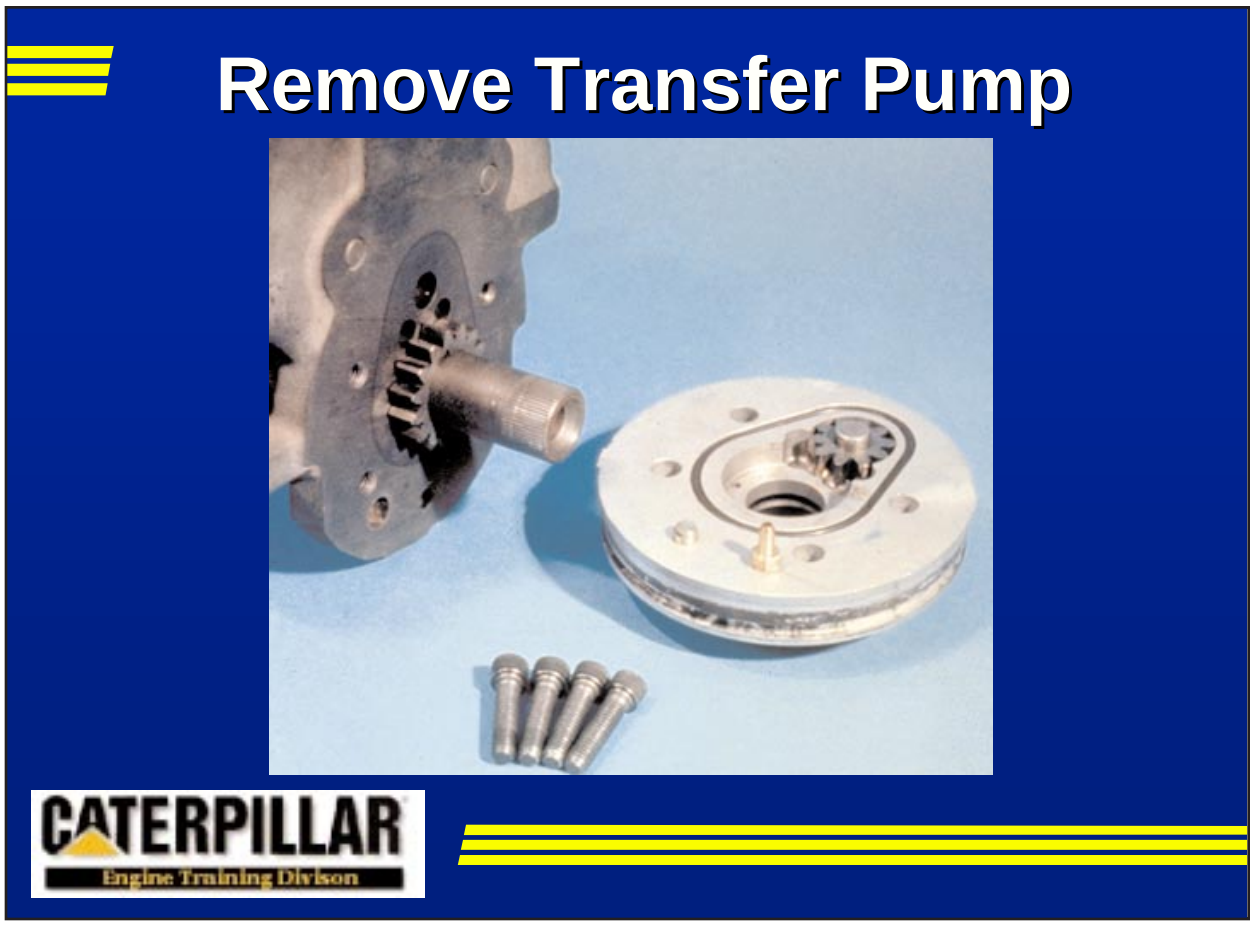
Install timing pin

Install the 3P1544 timing pin and turn the injection pump camshaft until the timing pin drops into the groove. This will stop the turning of the camshaft.



SLIDE 210

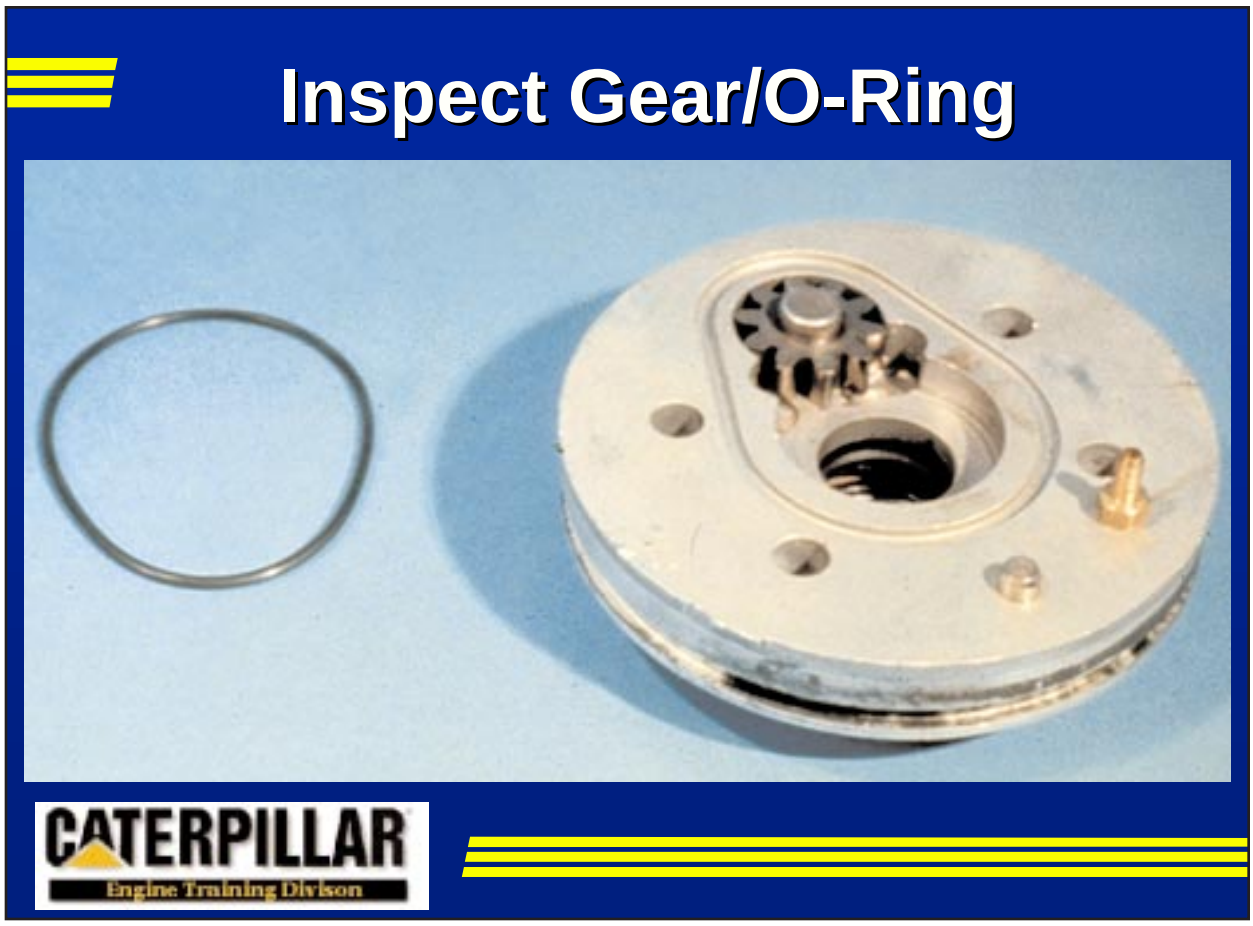
Turn the 2H3740 bolt that is found in the sleeve metering tool group into the end of the tapered drive adapter to remove it.



SLIDE 211

Remove bolts

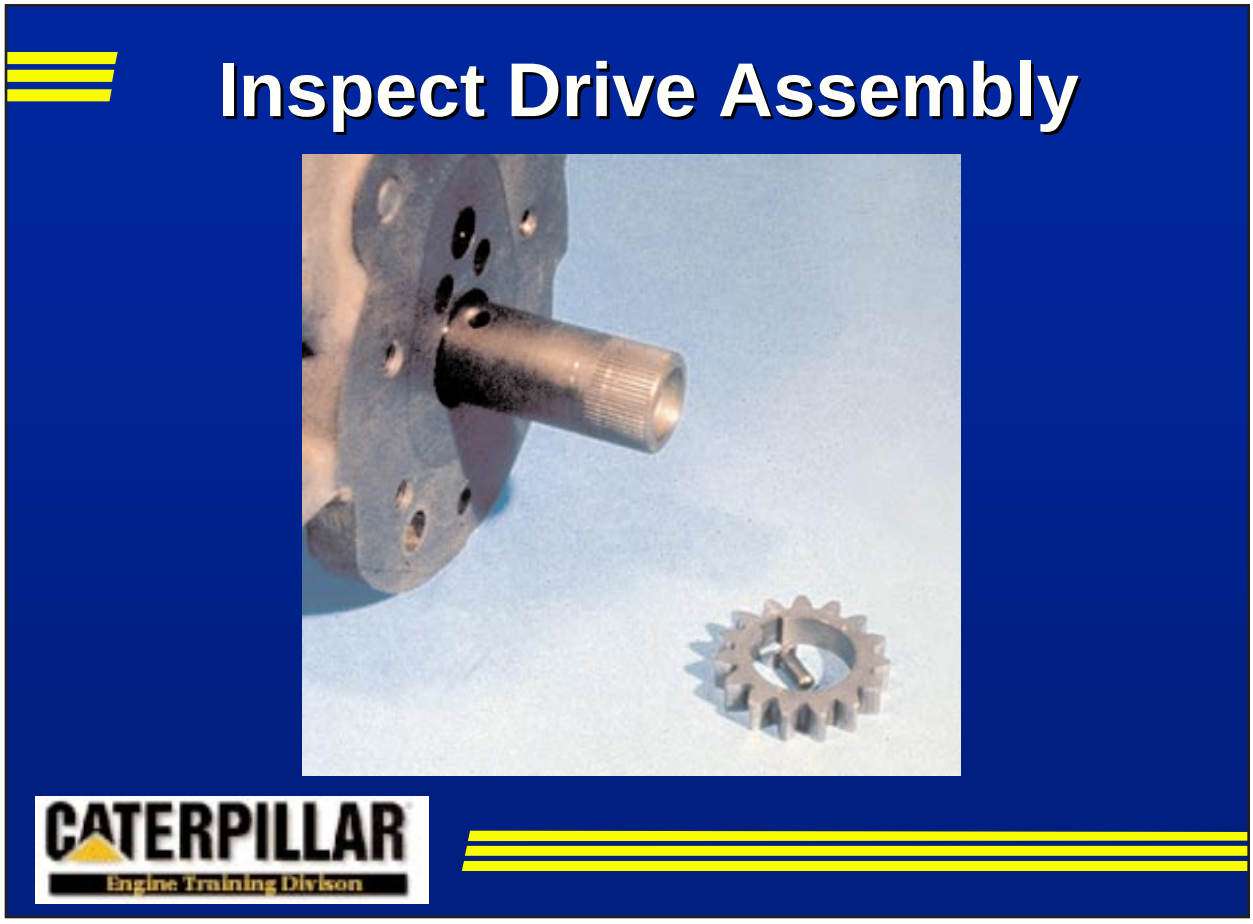
Remove the bolts in the transfer pump cover to the injection pump housing.



SLIDE 212

Inspect gear & seals

Inspect the idler gear internal lip-style seals in the camshaft bore and O-ring seal.



SLIDE 213

Inspect gear & key

Reassemble

Inspect the drive gear and key. Reassemble the fuel transfer pump.

SMALL ENGINE FUEL SYSTEMS

Lesson Plan 19 - 3208 Fuel System Lab

Objectives:

- The student will be able to remove and install a 3208 fuel pump and governor from the engine.
- The student will be able to completely disassemble and assemble the fuel pump and governor, and make appropriate internal adjustments of the pump and governor given the proper tooling..

Literature Needed:

6V4141 Sleeve Calibration Tool	SMHS7835
5P6577 Fuel Setting Tool Group	SMHS7013

Hardware Needed:

3208 Engine with Pump and Governor

6V4141 Sleeve Calibration Tool Group

5P6577 Fuel Setting Tool Group

Hand Tools

Time Required:

1.5 Hour

Tasks Required by Instructor to Meet Objectives:

1. Remove the fuel pump and governor from the engine if required.
2. Using the literature provided, disassemble, assemble and adjust, as required, the fuel pump and governor.
3. Re-install the fuel pump and governor on the engine if required.

SMALL ENGINE FUEL SYSTEMS

Lesson Plan 20 - Introduction to Fuel Lines and Nozzles

Objectives:

- The student will be able to identify the difference between failure modes of fuel lines on a written test with at least 70%.
- The student will be able to identify the difference between nozzle types, nozzle application and failure modes of fuel fuel injection nozzles on a written test with at least 70%.

Literature Needed:

Analyzing Fuel Nozzle and Fuel Line Failures SEBD0639

Hardware Needed:

None

Time Required:

1.5 Hour

Tasks Required by Instructor to Meet Objectives:

1. Using Analyzing Fuel Nozzles and Fuel Line Failures, explain the following:
   A. Capsule Nozzles
      1. PC Nozzles
         a. Single orifice/flat nose
         b. VOP (Valve Opening Pressure)
            1. Test Stand 400-750 psi
            2. On engine 1500-2000psi
         c. Peak pressure 6000-7000 psi
         d. Uses a screen for final filter
      2. DI Nozzles
         a. Multiple orifices/spherical nose

b. VOP 2400-3100 psi
c. Peak pressure up to 10000 psi
d. Uses a screen for final filter

3. Failure modes
   a. Bulged fuel nozzles
      1. Torque
         a). Over torque
         b). Under torque
      2. Overheated engine
   b. Tip erosion
   c. Cracked case
   d. Damaged tip
      1. Wire brush
      2. External force

B. Pencil Nozzles
   1. Used mostly on 3208
   2. Purchased nozzle
   3. No final filter in the nozzle
   4. Failure modes
      a. Tip damage
         1. Wire brushing
         2. External force
         3. Tip break
      b. Broken spring
      c. Compression seal or teflon seal - overheat
      d. Ferrule damage

C. Fuel line adapters
   1. Used to bring the fuel line under the valve cover.
   2. 3208 adapter has an edge filter.

3. Other models have the final filter in the nozzle.
4. Fuel leaks are routed out through a small hole
5. Oil leaks could be failed o-ring

D. 7000 Series Nozzles
   1. Usage
      a. Pigtail - 3208
      b. Internal thread - 3400
      c. External thread - 3300
   2. All DI
   3. Failure modes
      1. Thread/adapter damage
      2. Bleed screw damage
      3. Tip damage/blown tip

E. Fuel Lines
   1. Different materials for differnent injection pressures
   2. All lines on an engine must be the same length to balance cylinder timing.
   3. Failure modes
      a. Excessive nut torque
      b. Tip damage
      c. Cracked washer
      d. Line breakage
         1. Cross beakage - vibration
         2. Longitudinal crack
            a). Pressure
            b). Material defect

SMALL ENGINE FUEL SYSTEMS

Lesson Plan 21 - Nozzle Test Lab

Objectives:

- The student will be able to properly test PC and DI capsule nozzles using the 5P4150 Nozzle Testing Group in a lab exercise.
- The student will be able to properly test 7000 series and Pencil type nozzles using the 5P4150 Nozzle Testing Group in a lab exercise.

Literature Needed:

Using the 5P4150 Nozzle Testing Group	SEHS7292
Test Sequence for Capsule Type Fuel Nozzles	SEHS7350
Test Sequence for 7000 Series Fuel Nozzles	SEHS9083
Test Sequence for Pencil-Type Fuel Nozzles	SEHS7390

Hardware Needed:

5P4150 Nozzle Test Group

Various Fuel Nozzles

Time Required:

1.5 Hour

Tasks Required by Instructor to Meet Objectives:

1. Using the 5P4150 manual explain the following:
    1. Test tooling
    2. Test set up procedure
    3. Test methods.
2. Using the various test sequence sheets, have the students run a test on each type of nozzle.

SMALL ENGINE FUEL SYSTEMS

Lesson Plan 22 - Final Test and Class Evaluation

Objectives:

- The student will take a final test to review and test the course material. A minimum of 70% accuracy is considered acceptable.

Literature Needed:

Final Test	Copy
Course Evaluation Sheet	Copy

Hardware Needed:

None

Time Required:

1.5 Hour

Tasks Required by Instructor to Meet Objectives:

1. Ask students for questions regarding material covered the previous day
2. Answer all questions using reference material. Be sure the students follow along in their reference material while the question is answered.
3. Administer Final Test.
4. Review Final Test, again using reference material to answer questions.
5. Have the students fill out the course evaluation

SMALL ENGINE FUEL SYSTEMS

Lesson Plan 22 - Final Exam

Select the best answer(s) - If the answer is false on a true/false, correct the question to make it true.

1. Low boost pressure can be caused by:
   A. Late Timing
   B. #2 diesel fuel
   C. High cetane
   D. 42 API @ 60 degree F fuel

2. Raising the governor high idle rpm will:
   A. have no effect on horsepower
   B. lower horsepower
   C. increase horsepower
   D. decrease set point

3. The fuel system on a 3208 is (uses) a:
   A. scroll type
   B. mechanical unit injector
   C. electronic unit injector
   D. sleeve metering type

4. An engine has a torque of 505 pound feet at 2600 rpm. What horsepower is it developing?

5. Which of the following can cause excessive black smoke?
   A. High idle set too low
   B. High fuel setting
   C. Injector timing dimension 0.5 mm high
   D. A and B
   E. B and C
   F. All the above

6. The best way to lower cloud point of a diesel fuel is:
   A. Add alcohol
   B. Add gasoline
   C. Add #1 diesel
   D. Add cetane
   E. All the above

7. Fuel dilution in a 1.1 liter engine can be caused by:
   A. A cut injector o-ring
   B. A loose bleed screw in 7000 series nozzle
   C. A broken transfer pump valve
   D. All the above

8. One gallon of diesel fuel, 37 API @ 60 degrees F, weighs:
   A. 7.206 lbs
   B. 7.001 lbs
   C. 6.993 lbs
   D. 6.910 lbs

9. Engine fuel settings should be adjusted to compensate for power loss with lighter fuels.

   A. True

   B. False

10. Always pour clean fuel into a new fuel filter element before you install it.

    A. True

    B. False

11. The most accurate fuel setting information can be found:

    A. The 0T/2T/0K fiche

    B. The Technical Information File

    C. On the Engine Information Plate

    D. In the Service Manual

    E. In the Testing and Adjusting Manual

12. The purpose(s) of the governor is to:

    A. Prevent engine overspeeding

    B. Keep the engine at the desired speed

    C. Increase/decrease engine power output to meet load changes

    D. All the above

13. The centrifugal force of the governor flyweights is opposed by the:

    A. Rack

    B. Governor spring

    C. Thottle

    D. Decelerator

14. The tolerance on the fuel setting measurements when adjusting the setting is:
    A. +/- 0.00 mm
    B. +/- 0.10 mm
    C. +/- 0.25 mm
    D. +/- 0.50 mm
    E. None of the above

15. BSFC (Brake Specific Fuel Consumption) is:
    A. Amount of fuel to produce rated horsepower for one hour
    B. Pounds of fuel per horsepower minute
    C. Pounds of fuel per horsepower hour
    D. Gallons of fuel per horsepower hour

16. The hydraulic oil pump on a 3126B HEUI engine is a seven piston, variable displacement axial piston pump.
    A. True
    B. False

17. On a 7000 series nozzle, the bleed screw is in the nozzle during the VOP test.
    A. True
    B. False

18. When setting injector synchronization on a 1.1 liter engine, the dial indicator is zeroed while the #1 rack is held at shut off.
    A. True
    B. False

19. Which of the following fuels will produce the most horsepower?

    A. JP4

    B. 39 API @ 120 degrees F

    C. 35 API @ 60 degrees F

    D. 33 API @ 30 degrees F

20. What is the corrected API for 43 API @ 110 degrees F?

21. Fuel timing is checked on a 3116 engine using the 8T5300 Timing Indicator Group.

    A. True

    B. False

22. What is the proper torque for the sleeve screw on the 3208 fuel pump?

    A. 2.8 foot pounds

    B. 2.8 inch pounds

    C. 25 inch pounds

    D. 25 newton meters

23. On a 3116 engine, what injectors can you set timing on if you are at top dead center compression stroke on cylinder number 6?

24. 3116/3126 HEUI engines will not start if the injection actuation pressure is lower than 735 psi on the IAPCV.

    A. True

    B. False

25. Pilot injection on a 3126E ends when:

    A. The barrel ball check closes

    B. The plunger groove aligns with the spill port

    C. The ECM briefly shuts off power to the injector solenoid

    D. The intensifier piston bottoms out

26. A 3126E truck engine with a rating of 175 hp @ 2200 is run on an engine dynamometer. It produces 171 hp at its rated rpm under the following conditions:

Fuel density	35 API @ 85 degrees F
Fuel temperature	75 degrees F
Inlet air temperature	100 degrees F
Air pressure	31”Hg

    What is the corrected horsepower?

    If the engine has 150,000 miles on it, is the engine operating within its horsepower specification

SMALL ENGINE FUEL SYSTEMS

Lesson Plan 22 - Final Exam

Select the best answer(s) - If the answer is false on a true/false, correct the question to make it true.

1. Low boost pressure can be caused by: D

   A. Late Timing

   B. #2 diesel fuel

   C. High cetane

   D. 42 API @ 60 degree F fuel

2. Raising the governor high idle rpm will: C

   A. have no effect on horsepower

   B. lower horsepower

   C. increase horsepower

   D. decrease set point

3. The fuel system on a 3208 is (uses) a: D

   A. scroll type

   B. mechanical unit injector

   C. electronic unit injector

   D. sleeve metering type

4. An engine has a torque of 505 pound feet at 2600 rpm. What horsepower is it developing?

   hp = (505 X 2600) / 5252

   hp = 250

5. Which of the following can cause excessive black smoke? B

   A. High idle set too low

   B. High fuel setting

   C. Injector timing dimension 0.5 mm high

   D. A and B

   E. B and C

   F. All the above

6. The best way to lower cloud point of a diesel fuel is: C

   A. Add alcohol

   B. Add gasoline

   C. Add #1 diesel

   D. Add cetane

   E. All the above

7. Fuel dilution in a 1.1 liter engine can be caused by: A

   A. A cut injector o-ring

   B. A loose bleed screw in 7000 series nozzle

   C. A broken transfer pump valve

   D. All the above

8. One gallon of diesel fuel, 37 API @ 60 degrees F, weighs: C

   A. 7.206 lbs

   B. 7.001 lbs

   C. 6.993 lbs

   D. 6.910 lbs

9. Engine fuel settings should be adjusted to compensate for power loss with lighter fuels. B - never

   A. True

   B. False

10. Always pour clean fuel into a new fuel filter element before you install it. B - never

    A. True

    B. False

11. The most accurate fuel setting information can be found: C

    A. The 0T/2T/0K fiche

    B. The Technical Information File

    C. On the Engine Information Plate

    D. In the Service Manual

    E. In the Testing and Adjusting Manual

12. The purpose(s) of the governor is to: D

    A. Prevent engine overspeeding

    B. Keep the engine at the desired speed

    C. Increase/decrease engine power output to meet load changes

    D. All the above

13. The centrifugal force of the governor flyweights is opposed by the: B

    A. Rack

    B. Governor spring

    C. Thottle

    D. Decelerator

14. The tolerance on the fuel setting measurements when adjusting the setting is: A

    A. +/- 0.00 mm

    B. +/- 0.10 mm

    C. +/- 0.25 mm

    D. +/- 0.50 mm

    E. None of the above

15. BSFC (Brake Specific Fuel Consumption) is: C

    A. Amount of fuel to produce rated horsepower for one hour

    B. Pounds of fuel per horsepower minute

    C. Pounds of fuel per horsepower hour

    D. Gallons of fuel per horsepower hour

16. The hydraulic oil pump on a 3126B HEUI engine is a seven piston, variable displacement axial piston pump. B -Fixed displacement

    A. True

    B. False

17. On a 7000 series nozzle, the bleed screw is in the nozzle during the VOP test. B - is removed

    A. True

    B. False

18. When setting injector synchronization on a 1.1 liter engine, the dial indicator is zeroed while the #1 rack is held at shut off. B - rack of the cylinder being synchornized is held at shut off

    A. True

    B. False

19. Which of the following fuels will produce the most horsepower? B

    A. JP4

    B. 39 API @ 120 degrees F

    C. 35 API @ 60 degrees F

    D. 33 API @ 30 degrees F

20. What is the corrected API for 43 API @ 110 degrees F?

    38.6 API @ 60 degrees F

21. Fuel timing is checked on a 3116 engine using the 8T5300 Timing Indicator Group. B - 128-8822 Tool Group

    A. True

    B. False

22. What is the proper torque for the sleeve screw on the 3208 fuel pump? C

    A. 2.8 foot pounds

    B. 2.8 inch pounds

    C. 25 inch pounds

    D. 25 newton meters

23. On a 3116 engine, what injectors can you set timing on if you are at top dead center compression stroke on cylinder number 6?

    1, 2, and 4

24. 3116/3126 HEUI engines will not start if the injection actuation pressure is lower than 735 psi on the IAPCV. A

    A. True

    B. False

25. Pilot injection on a 3126E ends when: B

    A. The barrel ball check closes

    B. The plunger groove aligns with the spill port

    C. The ECM briefly shuts off power to the injector solenoid

    D. The intensifier piston bottoms out

26. A 3126E truck engine with a rating of 175 hp @ 2200 is run on an engine dynamometer. It produces 171 hp at its rated rpm under the following conditions:

Fuel density	35 API @ 85 degrees F
Fuel temperature	75 degrees F
Inlet air temperature	100 degrees F
Air pressure	31”Hg

What is the corrected horsepower?

Corrected API	33.1 API @ 60 degrees F	0.992
Fuel temperature		0.990
Air temperature		0.993
Air pressure		0.997
Total correction factor	(0.992 X 0.990 X 0.993 X 0.997) = 0.972	
Corrected horsepower	0.972 X 171 hp = 166 hp	

If the engine has 150,000 miles on it, is the engine operating within its horsepower specification

166 / 175 = 0.95 (95%)

No, the corrected hp is off more than 3% from rated